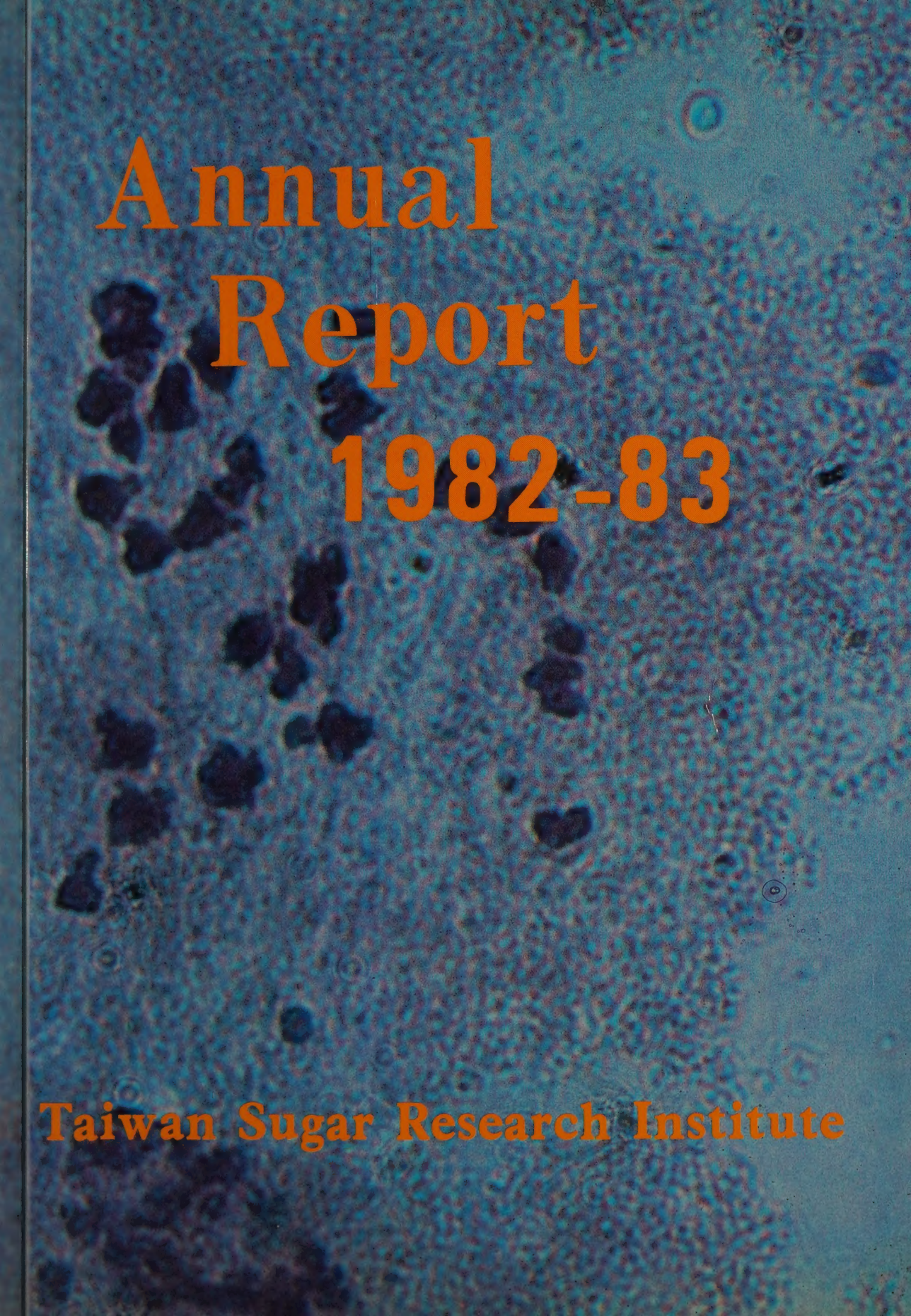


A microscopic image of plant tissue, likely a cross-section of a sugar cane stem, showing various cellular structures and dark, irregular spots that could be sugar crystals or areas of decay. The background is a mottled blue and green color.

Annual Report 1982-83

Taiwan Sugar Research Institute

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Annual Report

1982 — 1983

Taiwan Sugar Research Institute
Tainan, Taiwan, Republic of China

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COVER: Chromosome configuration of F146 x *Miscan-
thus* F₁ hybrid in metaphase, 2n = 94.

Foreword

Nowadays, in order to keep pace with the increasing demand resulted from the unceasing changes in the environments of sugarcane agriculture and sugar manufacturing, great effort has to be put to improve the overall efficiency on the one hand, and to diminish the cost of production on the other hand. The Taiwan Sugar Research Institute has been making every endeavor to obtain the most productive research results to prosper the sugar industry in Taiwan.

During the year, two new sugarcane varieties, ROC 7 and ROC 8, were released. ROC 7 is suitable for well irrigated sandy-loam and silt-loam soils. Its fast growing character makes it possible to reach a high level of sucrose content in early milling stage. ROC 8, characterized by its erect stalks and profuse tillering, is especially adaptable for gravel soils. During the whole growing stage, its available sugar content shows even higher than that of current varieties F170 and ROC 6.

To match with the use of liquid fertilizer in sugarcane field, a special application implement and a mixing and refilling trailer have been successfully developed in the Department of Agronomy. Beneficial result has been also obtained from research of syphon multiple well, with which the yield of well can be greatly increased.

In the Department of Plant Nutrition, significant result was obtained from the studies on nitrogen fixing bacteria associated with sugarcane roots. The research on nutrient recycling of hog manure also showed very promising result.

The Department of Plant Protection has made significant achievements in the research of sugarcane varietal resistance to major diseases in Taiwan; the host range and nutritional requirement of the causal organism of root and basal stem rot of sugarcane; and the occurrence of aphid vectors of sugarcane mosaic virus and their efficiency in transmission of different strains of the virus.

In the Department of Sugar Technology, significant resolutions were attained on the continuous sugar boiling process; the development of syrup clarification process for improving sugar quality; and the rapid assessment of biodeterioration in harvested cane.

Most of the research carried out in the Department of By-product Utilization appeared to be productive. Results with prominence were obtained from studies on the production of high quality food yeast; the alcohol fermentation by immobilized yeast cells; and the isolation of new L-lysine producing mutants.

Besides, a sophisticated 32-bit supermini computer, VAX-11/730 was installed during this year.

Hopefully, this Annual Report 1982–83 will present a guide-line for perceiving the objectives, endeavor and contribution of this Institute.

Research Achievement

Sugarcane Breeding

Release of New Varieties ROC 7 and ROC 8

Two new sugarcane varieties, ROC 7 and ROC 8, were officially released by the Taiwan Sugar Research Institute (TSRI) in May 1983.

The new variety ROC 7, Numbered as 73-5525 for the original seedling, was selected from the progeny of F160, the leading variety, pollinated by high sugar clone 60-2321. ROC 7 produces high tonnage of cane and its sucrose content reaches a high level in mid-December (Figs. 1 and 2). It is a fast growing, medium tillering, medium thick, and long stalked variety; adapted to well-irrigated land or sandy-loam, loam, or silt-loam soil with high underground-water table; and suitable for autumn and spring planting. Its ratooning ability is also satisfactory. ROC 7 is highly tolerant to the herbicides currently used in sugarcane fields. It is also highly resistant to mosaic; resistant to downy mildew; moderately resistant to smut, leaf blight, leaf scorch and red rot; and moderately susceptible to white leaf disease.

Another new variety ROC 8 with prominent adaptability to gravel soil was select-



Fig. 1. New variety ROC 7 at maturing stage.

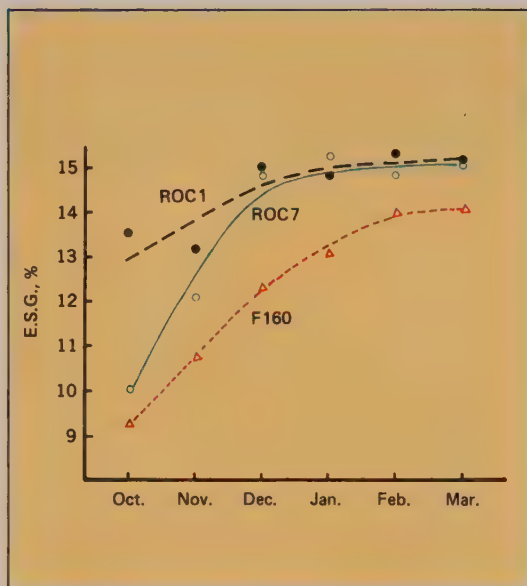


Fig. 2. Monthly changes in sugar content of ROC 7 in comparison with F160 and ROC 1.

ed from the progeny of F146 pollinated with F160 and designated as 73-6531 at seedling stage. ROC 8 is a fast growing variety having excellent ability of germination even at wilting point and low temperature. It has profuse tillers and millable stalks of medium-thin size, and noted for its superior characters of anti-lodging and wind resistance. The sucrose content of ROC 8 has been greatly improved when compared with that of F170 and ROC 6 currently recommended for gravel soil (Figs. 3 and 4). Yield trials of autumn planted cane and ratoon conducted on gravel soil showed that both cane and sugar of ROC 8 outyielded significantly over the standard variety F170. ROC 8 is highly resistant to downy mildew; resistant to leaf scorch; moderately resistant to smut, red rot and white leaf disease; and susceptible to leaf blight. (Lo, C. C.)



Fig. 3. New variety ROC 8 at maturing stage.

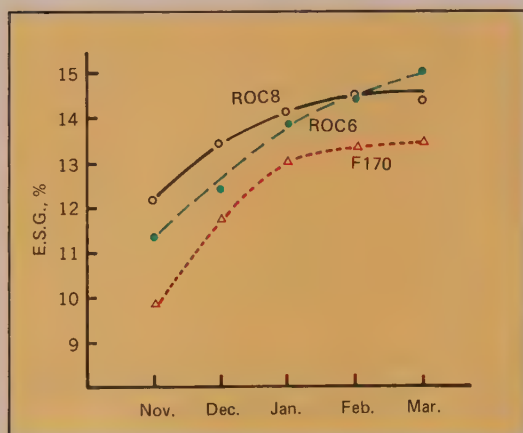


Fig. 4. Monthly changes in sugar content of ROC 8 in comparison with F170 and ROC 6.

Variety Census for 1982–83

Thirty-two commercial varieties were under cultivation in Taiwan for the crop year 1982–83. All of them were the varieties bred and released by TSRI except NCo310, which occupied only 0.45% of the total acreage of 86,743 ha. F160, F177 and ROC 5 were still the top three varieties, occupying 34.39%, 10.96% and 10.13% of the total acreage, respectively (Table 1). The acreage of ROC 5 increased by 3.12% as compared with that in last year, since farmers were in favor of a heavy tonnage variety. The very early maturing and high sugar variety ROC 1 came up to 4th position as expected, however, the increment in acreage was not so contented because of

its tardy germination in ratoon. F178 came up from 8th last year to 5th this year, and showed excellent adaptability to the humid and well irrigated soils in Pingtung area. Newly released varieties ROC 7 and ROC 8 are expected to occupy some acreage in Huwei and Pingtung areas, respectively, in the coming year. (Lo, C. C.)

Table 1. Percentages of the acreage of principal varieties in 1982–83

Variety	% acreage
F160	34.39
F177	10.96
ROC 5	10.13
ROC 1	6.39
F178	4.03
F176	3.79
F171	3.71
F154	2.90
F170	2.84
F146	2.62
F166	2.14
ROC 3	1.81
F156	1.79
ROC 2	1.66
ROC 4	1.53
F167	1.40

Crossing

The 1982–83 sugarcane crossing season was characterized by the heavy and synchronized flowering in a short period in early December. The crossing work started on October 8, 1982 for the photoperiod-treated varieties, and on November 19 for the parent varieties grown in the crossing nursery. The crossing season ended on January 19, 1983. A total of 4,329 tassels of fuzz, a record-breaking quantity in recent 10 years, were obtained this season (Table 2). Among them, 2,338 tassels were from marcotting and 1,991 from modified SO_2 method. The number of combinations and tassels obtained are shown in Table 2. (Lo, C. C., Kwo, C. Y., and Huang, Y. J.)

Table 2. Sugarcane crosses made in 1982-83

	No. of combinations	No. of tassels
Commercial cross	503	2,369
Test cross	841	1,960
Total	1,344	4,329

Seedling Raising in 1983

Seeds from 2,044 tassels were sown on methyl-bromide-sterilized seed beds as usual at nine field stations, and a total of 467,838 seedlings were raised and single-planted. The unsown fuzz were deep-frozen for use at incidental condition. The numbers of tassels sown and seedlings raised in 1983 are given in Table 3. A serial number 83 will be given to these seedlings.

Table 3. Seedlings raised in 1983

Field station	No. of combinations	No. of tassels	No. of seedlings planted
Houli	96	208	34,410
Huwei & Hsialiao	84	178	40,038
Hsingying	76	160	37,068
Tainan & Shaluen	210	547	145,883
Wantan	286	588	144,253
Changlung	110	200	37,480
Hualien	81	163	28,701
Total	953	2,044	467,838

Selection

The number of clones of each series selected at nine field stations are listed in Table 4. For series 82, a total of 8,931 clones were selected from single-planted seedlings and each clones was propagated in one-row plot of 6 m long with 1.37 m width (T_1 stage). Every 10 rows of new

Table 4. The number of clones selected at field stations in 1982-83

Field station	82 series	81 series	80 series
Houli	945	212	77
Huwei	730	150	32
Hsialiao	302	70	12
Hsingying	554	181	75
Tainan	1,865	230	88
Shaluen	330	68	19
Wantan	2,756	607	150
Changlung	573	160	62
Hualien	876	177	83
Total	8,931	1,855	598

clones were separated by one row of check variety, the leading commercial variety in the area. After the selection made at T_1 stage, 1,855 clones of series 81 were propagated in 4-row plots of 6 m long (T_2) for further observation of their characters. For series 80, a total of 598 clones were selected and some superior clones were placed in the varietal test (T_3). The rest remained at T_2 stage for further evaluation.

Varietal Test

The varietal test (T_3) of 241 clones selected from the T_2 stage was accomplished this year at 6 field stations. The field layout was 1.37 m x 6 m (or 8 m) x 8 rows x 3 replications. At each station, one or two of the leading commercial varieties in the area were used as check varieties for comparison. Among the tested, 5 clones from series 77, 3 from series 78 and 12 from series 79 outyielded check varieties, showing their superiority in cane and sugar yields.

Regional varietal test (stages T_4 and T_5) were conducted as in the previous year at 41 plantations of 25 sugar factories and 3 experiment stations. A total of 121 clones were being tested at regional observation stage (T_4) in unreplicated plots of 6 - 8 m x 4 - 6 rows. The eminent clones selected

from the T_4 stage in the previous year were promoted to stage T_5 , employing plots of 1.37 m x 6 m x 8 rows with 4 to 6 replications. In this year, 127 clones received T_5 test conducted at 41 plantations.

Three clones, namely 74-6620, 75-3439 and 76-685, showing superior characters and good yields at T_5 stage will enter the advanced regional test (T_6) in the coming year. Their characters are:

74-6620 – a selection from the cross 64-19 x 51-213; prominent for its very early maturity, high sucrose content and high tonnage of cane; best adapted to gravel soil.

75-3439 – a progeny of a cross F171 x F166; performed outstandingly in many locations with high tonnage of cane and high sugar yield; highly resistant to downy mildew, leaf blight and smut.

76-685 – a derivative from a cross ROC 5 x F152; has shown excellent performance on heavy soil and saline soil; with higher levels of sucrose content and disease resistance than the female parent ROC 5.

Induction of Tasselling by Red Light

Plants of sugarcane varieties F157, F160 and F167 were exposed to 12¼ hr. light supplemented with red light (R) and far-red light (FR) twice daily at 6 to 8 am and 4 to 6:15 pm, instead of using incandescent light, for induction of tasselling. The experiments were conducted from July 15 to December 15, 1982.

Encouraging results were obtained with $FR \rightarrow R$ and $R + FR \rightarrow R + FR$ combinations of supplemental illumination. When a non-tasselling variety F157 was treated, 23.1% and 9.1% of the plants tasseled, respectively, while no induction of tasselling was found in the control treatment of illumination with incandescent light. A shy tasselling variety, F167, responded well to $R + FR \rightarrow R + FR$ illumination combinations and 45.5% of the plants tasseled in comparison to none in the control. With $FR \rightarrow R$ and

$R + FR \rightarrow R + FR$ treatments, percent tasselling in another shy variety F160 increased to 50% and 22.2%, respectively, but it was only 11.1% in the control.

Combinations of supplemental illumination $R \rightarrow R$, $FR \rightarrow FR$ and $R \rightarrow FR$, were also tested. However, their effect on induction of tasselling was insignificant. (Chang, Y. S., Huang, Y. J., and Kwo, C. Y.)

Delay of Tasselling by Long-Day Photoperiodic Treatment

Sugarcane varieties and clones of *Saccharum-Miscanthus* hybrids of early and profuse tasselling were tested again this year with long-day photoperiodic treatment for the purpose of delaying tasselling.

When plant materials were about to reach initiation of floral primordia, they were exposed to 13 hr. light for 30 days from August 21 to September 20 followed immediately by 30- or 15-day exposure to 12¼ or 12.5 hr light. The light intensity was measured as 250 lux at the plant top.

Sugarcane varieties F146, F173 and CP 65-357 failed to tassel under the long-day treatments. However, the first tasselling in L60-25 was significantly delayed for 35 to 56 days when compared with that in the plants grown under natural light condition. Three F_1 clones of *Saccharum-Miscanthus* hybrids, SM-7926, SM-7937 and SM-7957, also responded positively to the long-day photoperiodic treatments, showing 2 to 28 days of delay in tasselling. The delayed tasselling in *Saccharum-Miscanthus* hybrids actualizes the possibility of nobilization through crossing with sugarcane varieties. Regardless of the photophase periods tested, exposure of the plants to 13 hr light and then to 12.5 hr light was more effective than the treatment of exposure to 13 hr light followed by 12¼ hr light in delay of tasselling.

Another treatment of 30-day exposure to 18 hr light started on July 1 followed by

62-day exposure during September 21 to November 20 completely inhibited the tasselling in all of the varieties and clones tested. (Huang, Y. J., Kwo, C. Y., and Tu, T. T.)

Delay of Tasselling by Leaf Trimming

The results of experiments on trimming off the spindle of sugarcane at -1 leaf and above twice on the 7th and 10th days after the initiation of floral primordia for the delay of tasselling in early-flowering sugarcane varieties were encouraging.

The first tasselling in F146, F173, CP 65-357 and L 60-25, were delayed for 2 to 16 days by trimming off the spindles. Three clones of *Saccharum-Miscanthus* hybrids also showed 3 to 20 days of delay in tasselling when they were trimmed.

The percentages of tasseled stalks decreased slightly in the trimmed varieties and clones except L 60-25. As a result of this experiment, 58 tassels of fuzz were obtained from 24 combinations of the treated materials. (Huang, Y. J., Kwo, C. Y., and Tu, T. T.)

Drought and Salt Resistance in *Saccharum* × *Miscanthus* Hybrids

Five clones of *Saccharum* × *Miscanthus* hybrids (F_1) were tested for their resistance to drought and salt at Houli and Yiwu, respectively. It revealed that growth of the F_1 hybrids were superior to that of local commercial variety during the whole growing period (Fig. 5). The F_1 hybrids were back-crossed with commercial varieties for nobilization. Ninety-three clones of the back-crossed hybrids (BC_1) have been selected for further utilization of the *Miscanthus* germplasm, and the test on their reaction to downy mildew and smut disease is underway now. (Lo, C. C., Chen, W. H., Huang, Y. J., and Shen, I. S.)



Fig. 5. Ten-month-old plants of *Saccharum-miscanthus* F_1 hybrid, SM-7988, showing superior growth on saline land as compared with the check variety, ROC 3.

Utilization of *Saccharum Spontaneum*

Utilization of *S. spontaneum* in sugarcane breeding program has been carried out for several years. A few clones that might be of value as breeding line were obtained recently. An interspecific hybrid, 70-4255, selected from the progeny of sugarcane variety F152 crossed with *S. spontaneum* 66 S 82, was found to be promising. The numbers of somatic chromosomes ($2n$) of F152 and 66 S 82 are 114–115 and 96, respectively. With the chromosome number of $2n = 108$, the hybrid 70-4225 was determined to be derived from a zygote, of

Table 5. Chromosome number and configurations in first meiotic division of *S. spontaneum* 66 S 82, sugarcane variety F152, and F_1 hybrid 70-4255

Clone	Chromosome configuration	$2n$
66 S 82	48 II	96
F152	55 II + 4 I 56 II + 2 I 56 II + 3 I	114, 115
70-4255	52 II + 4 I 53 II + 2 I 54 II	108

which both male and female parents contributed a haploid set of chromosomes (Table 5). (Hsu, S. Y., and Lo, C. C.)

Growth Characteristics and Nutritional Requirements of Sugarcane and Soybean Protoplasts

Due to a nonspecific characteristic of polyethylene-glycol-induced fusions, the fusion products of protoplasts from sugarcane and soybean contain a variety of fused and unfused protoplasts. It is one of the useful selection procedures that selection of the true heterokaryotic hybrid cells from the mixed population of the fusion products of protoplasts depends on the growth pattern in comparison with the parental protoplasts.

Soybean (*Glycine max.* L. cv. Davis) protoplasts from cell cultures would regenerate a cell wall within 12 hours after isolation and enter cell divisions within 24 hours, if the washed protoplasts were cultured in SP₁ liquid medium at 26° C (Fig. 6). The SP₁ medium was composed of Gamborg B₅ (1968) mineral salts and vitamins + 0.38 M Glucose + 3.1 mM NH₄NO₃ + 1.66 mM Xylose + 0.4 mM CaCl₂ · 2H₂O + 0.4 mM Ca(H₂PO₄)₂ + 1-g/l Casein hydrolysate + 1 mg/l 2,4-D + 1 mg/l BAP + 20 ml/l Coconut milk, pH 5.5. However, the sugarcane protoplasts lysed completely when

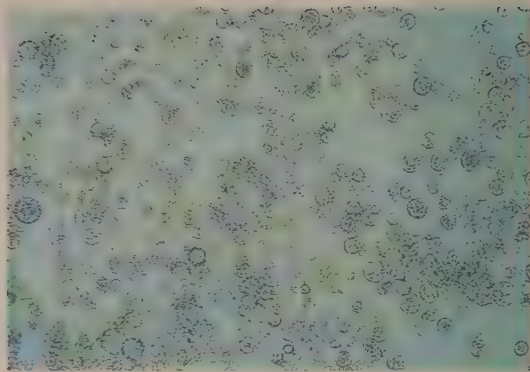


Fig. 7. Protoplasts of sugarcane lysed in the SP₁ medium when they were suspended in the medium for 48 hours. X 64.

they were suspended in the SP₁ medium for 2 days (Fig. 7).

A P₉ medium modified from Murashige and Skoog medium (1962) could extend the viability of sugarcane protoplasts to 20 days and support cell divisions (Fig. 8). On the contrary, the soybean protoplasts cultured in the P₉ medium stopped to grow into cell clusters (Fig. 9). It was noted that sugarcane protoplasts required a medium with 100 mM CaCl₂ and 750 mOs/kg osmotic pressure to sustain cell growth; but the soybean protoplasts needed a medium with 4 mM CaCl₂ and 500 mOs/kg osmotic pressure to support cell division. A selection procedure based on the difference in growth patterns between the sugarcane and soybean protoplasts has been designed to select the true somatic

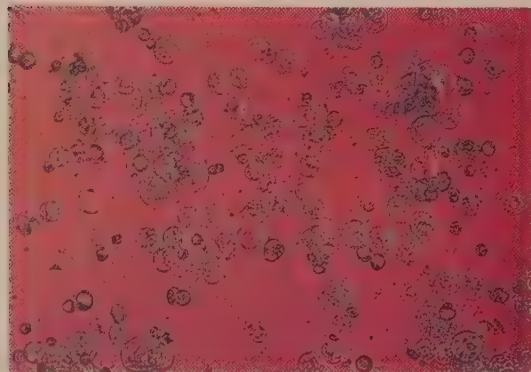


Fig. 6. Divisions of soybean protoplasts in the SP₁ medium 24 hours after isolation. X 64.

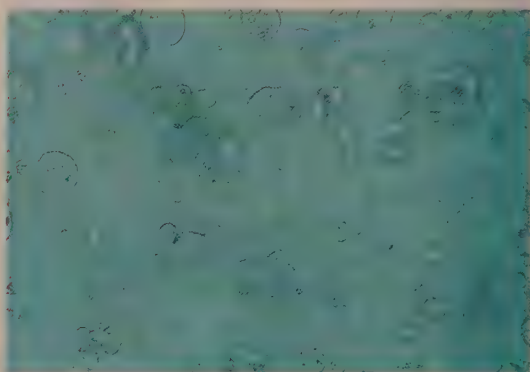


Fig. 8. Cell divisions of sugarcane protoplasts cultured in the P₉ medium for 12 days. X 64.

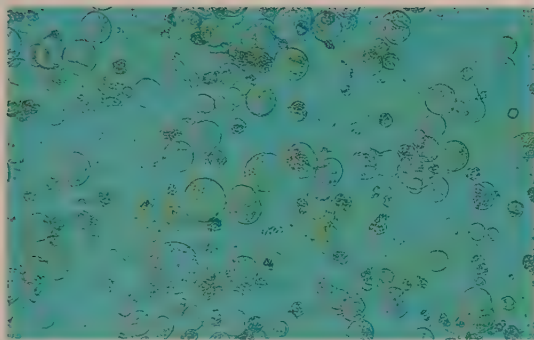


Fig. 9. Soybean protoplasts cultured in the P_9 medium for 14 days, showing most of the protoplasts enlarged to several times of the initial size, but no division. X 64.

hybrid colonies from the mixed fusion products of sugarcane and soybean protoplasts. (Chen, W. H., and Liu, M C.)

Regeneration of NaCl-tolerant Sugarcane Plants

The differentiated shoot-buds of F177 were subjected to pre-selection on 1.17%



Fig. 10. NaCl-tolerant plants (right) growing normally on a salting soil as compared with the plants (left) on control soil.

NaCl medium. The shoots survived were laid down on MS medium with either 0.94% or 1.17% NaCl. Calli were re-initiated at the base of the surviving shoots and concomitantly some of the calli re-differentiated into shoots. The new shoots were continuously subcultured on 0.95% NaCl medium for growing them to largeness. The salt-tolerant plantlets were raised to 20–30 cm in height. Then they were planted in the soil with salt strength of 10 mmhos/cm electric conductivity. After five months of growth, they appeared as vigorously as the plants on control soil (Fig. 10) even they had accumulated more Na^+ and Cl^- ions. (Liu, M. C., Yeh, H. S., and Chen, W. H.)

Cultivation

Effect of Dual-row Planting on the Yield of Sugarcane

Field experiments were conducted during 1978–83 to evaluate the effect of dual-row planting with wide row spacings on the growth and yield of sugarcane. The variety F160 was planted in dual row 40 cm apart with row spacings of 200 and 180 cm or 25 cm apart with row spacings of 170 and 150 cm. Conventional single row planting with a row spacing of 125 cm was used as check.

The results showed that the millable stalk population per hectare at harvest was greater in the check than that in dual-row planting for both plant and ratoon canes. However, the number of dead stalks per hectare at harvest was much less in dual-row planting than that in the check.

Cane yields of the plant cane and two ratoons averaged 108.4 and 109.2 mt/ha in the dual-row with spacings of 200 and 180 cm, respectively. It was decreased in yields by 7 and 6% comparing with that in the check which yielded 116.3 mt/ha. While in dual-row with spacings of 170 and 150 cm, cane yields were 100 and 102.4 mt/ha,

respectively, and 9 and 6% lower than the check which presented a yield of 109.7 mt/ha.

In view of the results, it is suggested that the dual-row planting with a row spacing of 150 cm would be an acceptable alternative to the conventional single row planting with a row spacing of 125 cm in favour of field mechanization under the present cane cultural conditions in Taiwan. (Yang, P. C., and Ho, F. W.)

Influence of the Times of Planting and Harvesting on Cane and Sugar Yields of Newly Released Varieties

In order to investigate the influence of the times of planting and harvesting on cane and sugar yields, the new sugar cane variety ROC 7 and a promising clone 71-6063 were tested in Huwei (loamy soil) and Hsingying (clay soil), while varieties ROC 6 and ROC 8 were tested at Hsinghua farm (gravel soil) in Pingtung.

ROC 7 was officially released for commercial cultivation this year. It showed many good agronomic characters including high yields of cane and sugar in Huwei and Hsingying areas. Its mean yields of cane and sugar in Autumn planting canes were 135 mt/ha and 19 mt/ha, respectively. The clone 71-6063 also showed an excellent yield performance in both tested areas, however, further evaluation for its resistance to downy mildew and smut diseases is needed.

Both ROC 7 and 71-6063 planted in

early August in Huwei and Hsingying showed a significant increase in yields of cane and sugar than that planted in late September and November. The similar trend in favour of early planting was also found in Pingtung area.

ROC 8 was officially released this year. Both ROC 6 and ROC 8 seemed to be very adaptable to gravel sandy soils. On the average, these two varieties yielded 95 mt/ha of cane on the coarse gravel sandy soil. As for the harvesting times, no significant differences in cane and sugar yields were found among the treatments of harvesting in December, February and April at the three tested sites. (Agronomy Department)

Sugarcane Root Distribution in Relation to Growth and Maturity

A field experiment was carried out on sandy loam soil in Tainan to study the root system of new sugarcane varieties in relation to growth and maturity. Results revealed that cane varieties differed in root distribution patterns. The roots of ROC 6 and ROC 8 penetrated into the soil more deeper than those of ROC 3 and ROC 7 (Fig. 11). With different levels of irrigation treatments, i.e., PR (pan ratio) 0, 0.4 and 0.75, it was found that the response of cane growth to soil moisture was more sensitive for varieties ROC 3 and ROC 7, but less for ROC 6 and ROC 8. In other words, the effect of soil moisture stress on growth was more greater for ROC 3 and ROC 7.

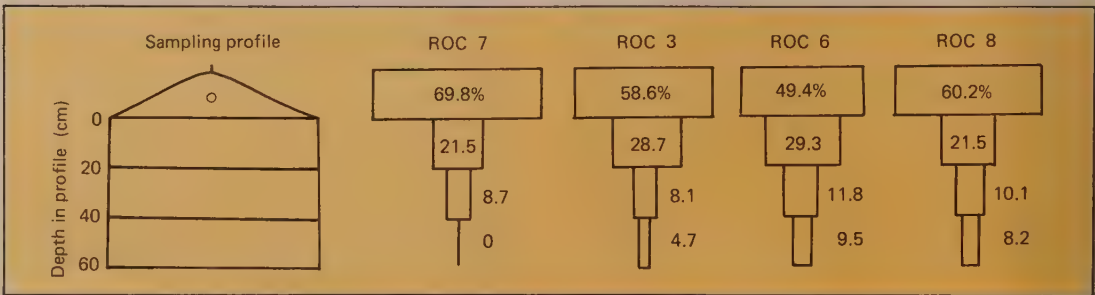


Fig. 11. Root distribution of new sugarcane varieties.

The monthly changes in cane brix during the period from September to January showed that the maturity was markedly affected by soil moisture regimes for ROC 3 and ROC 7. An appropriate deficits of water supply at harvest time increased conspicuously the brix of stalks for ROC 3 and ROC 7, but insignificant for ROC 6 and ROC 8. Therefore, adequate irrigation during the growing period and proper control of soil moisture at maturity are required for obtaining higher sugar yields for ROC 3 and ROC 7, both of them were with shallow root systems. (Sheu, Y. S., and Yang, P. C.)

Influence of Soil Moisture on Early Development of Ratoon Cane

The improvement of soil moisture management during the early stage of ratooning was in favour of the physiological activities of the ratoon stubbles and buds, and yield a better sprouting and early growth of the

ratoon cane.

Soil moisture at four levels was adjusted by irrigation on sandy loam soil. The treatments are: W₀, non-irrigated; W₁, irrigated at an interval of six weeks; W₂, of three weeks; and W₃, of two weeks. Each irrigation cycle lasted for six weeks; and a period of two cycles was made right after the harvest of the preceding crop. Investigations was focused on the young ratoon plants (Table 6).

It showed an increase in shoot weight and stalk height with the increase of soil moisture in both varieties of F160 and ROC 1. The same tendency was also found in the root weight, root length and the number of roots, except the treatment W₃. The difference in shoot weight, root length and the number of roots among treatments was significant at 5% level. It implied that the higher soil moisture content on medium-textured soil would provide a better condition for the early development of ratoon canes. (Wei, C. C., and Yang, P. C.)

Table 6. Influence of soil moisture on early development of the shoot and root of ratoon canes

		Soil moisture treatment			
		W ₀	W ₁	W ₂	W ₃
Fresh shoot weight (g/plant)	F160	63.4	70.6	67.8	80.3
	ROC 1	64.8	71.3	79.3	83.2
	Mean	64.1a	70.9ab	73.5b	81.7b
Stalk height (cm)	F160	21.9	22.9	22.8	24.0
	ROC 1	22.4	22.4	24.5	24.8
	Mean	22.2a	22.7a	23.7a	24.4a
Fresh root weight (g/plant)	F160	1.4	2.0	2.2	1.0
	ROC 1	2.2	1.9	3.2	3.2
	Mean	1.8a	2.0a	2.7a	2.1a
No. of roots per plant	F160	7.5	8.5	9.9	7.0
	ROC 1	11.8	9.6	18.6	14.7
	Mean	9.6a	9.0a	14.3b	10.8ab
Root length (cm/plant)	F160	44.4	45.1	63.9	36.4
	ROC 1	63.5	52.7	125.5	120.2
	Mean	54.0a	48.9a	94.7b	78.3ab

Means not followed by the same letter differ significantly at 5% level.

Germination Response of Promising Clones to Temperature

Setts of three promising sugarcane hybrid clones, 71-4053, 73-515, and 74-6133, were planted in growth chambers with temperatures at 30, 26, 26, 22, 18 and 14° C to test their germination response.

Results showed that 73-515 germinated quite well at any temperatures above 18° C. However, the germination speed of 71-4053 and 74-6133 was drastically slackened as the temperature was down blow 22° C. Comparatively, 73-515 was considered with tolerance to lower temperature, while 71-4053 and 74-6133 were not. The temperature being as low as 14° C was too low for the germination of the tested clones, only one bud emerged from 73-515, but none from the other two clones. (Chen, J. B., Chiu, Y. M., and Yang, P. C.)

Climate and Sugarcane Growth

The climate of 1982 over sugarcane growing areas of Taiwan was normal with mid-level temperature, less rainfall and two typhoons, which had made serious damage to sugarcane over the southeast of Taiwan and resulted in lower yield for 1982–1983 crop years.

The annual rainfall in 1982 was 24% less than that in 1981, especially from March to April, the rainfall was only about half amount of that in 1981 over the southern Taiwan.

In spite of less rainfall it did not give more sunshine as it should be. The sunshine hours was 8% below average during this period. Both the severe water deficit and less sunshine had caused poor growth for the young canes in their early growing stages. The number of cane stalks in June was 20% less than that of the previous year. This might be the primary factor resulting in low yield of this crop year.

Three typhoons passed through or across

the border of Taiwan in 1982, namely ANDY on July 29, CECIL on August 9, and DOT on August 15. ANDY and CECIL hit the southeastern part of the island and had made a bad damage to Taitung and Hualien areas. As a result, 10% of cane damage was recorded.

During the later period of cane growth, an extraordinary drought brought in clear and dry weather lasting from September to mid-November, which was unfavorable to sugarcane growth. On the contrary, more daily range temperature and sunshine had provided a favorable condition for ripening and thus, increased 10% of sugar content in the early milling period than that of 1981. However, after November the abundant rain-fall broke the records of 85 years, thus wet weather and less sunshine during the mid and later part of the milling season depressed the accumulation of sucrose. With those beneficial and adverse effects, the sugar content of the 1982–83 crop year was not as high as primarily expected. (Tang, R. T., Su, W. P., and Jian, K. Y.)

Equipment for Liquid Fertilizer Application

An applying implement and a mixing and refilling trailer were fabricated last year in accordance with the application of liquid fertilizer in sugarcane field.

The applying implement is of the tractor mounted type, which makes it feasible to accompany with any other kind of cultivation implements. Two tanks containing 327 liters each are mounted to both sides of the tractor. The piston pump is powered hydraulically by a Char-Lynn motor through tractor remote with breakaways. The application rate is controlled by the valves in the distribution manifold.

The mixing and refilling trailer functions by mixing the ingredients with the base solution and refilling it to the applying implement in the field. The mixing is achieved by the circulation of the base solution which

is actuated by electrically powered pump. A small gasoline engine is used to drive the re-filling pump. The piping system makes it possible to agitate the mixed solution before refilling. (Wang, W. H.)

Improvement of the Earthing-in Implement for Sugarcane

Several types of earthing-in implements have been devised and tested in order to supersede the conventional hoe or spade in earthing-in operation, which functions to bring into the middle of the cane stool a certain quantity of soil at the time of tilling stage. Two types of the implements are currently used, namely lister plus rotary blade and backward rotary tiller.

In the former type, the rotational blades are set above the moldboard, used to pulverize the soil slice moving up on the moldboard and scatter it along the cane rows. In order to improve its operating efficiency, a screw was newly added to each of the blade spindle for smooth intake of soil. In the latter type, the rotary tillers are used to pulverize the clods and throw it along the guide cover. A small subsoiler was added in front part of the implement, and the newly designed knife was set to help reducing the energy consumption and calm down the fierce vibration during operation. (Wang, W. H.)

Loads Imposed on Tractor Engine and PTO Shaft by Rotary Tiller and Cultivator

In recent years the power take-off of agricultural-type tractors has steadily increased in use as a means of transmitting engine power to rotary implements, because it possesses the advantage of driving the implements continuously when the forward motion of the tractor is stopped. But the improper joint angle of power take-off shaft causes marked fluctuation of torque, thus reducing the life of PTO driveline.

Test results showed that the horsepower required for the rotary tiller with a working depth of 13 cm on clay soil field was 57.2 PTO HP, while that for rotary cultivator was 48.8 PTO HP. (Fig. 12) The maximum power of Ford 6600 tractor is 70.1 PTO HP, which exceeds that required for operating either rotary tiller or rotary cultivator.



Fig. 12. Testing the loading of rotary tiller (above) and cultivator (below) on tractor in field operation.

However, under the same test condition, close attention must be given to the maximum instantaneous torque of 150.4 kg-m, reaching the value of 120% of the average peak torque, when the shaft joint angle is 16° .

Test results also indicated that when rotary cultivator operated with a working depth of 10 cm on loam soil field, the average torques required were 68.6 kg-m and 62.5 kg-m for joint angles of 16° and 12° , respectively. Obviously, reducing PTO shaft

joint angle can correct torsional vibration and torque requirement, and thereby improve the performance of the implement as well as reduce the load on the tractor engine and PTO driveline. (Huang, L. H.)

Weed Control

Panicum repens Controlled by the Mixture of Glyphosate and Surfactant

Weed control with herbicide is the most efficient and convenient means at the present time. Due to the long term application of the same characteristicness of herbicides, a change in ecology of weeds from annual to perennial or even to some tolerant weeds has been eventually caused. *Panicum repens* is one of the most tolerant grass weeds in sugarcane fields. The commonly used herbicides such as dalapon, asulam, and metribuzin could not eradicate the weed from fields. It has bothered to both the researchers and farmers for a long time. However, this problem has been resolved immediately after glyphosate was introduced and recommended on control of the weed. The rate of glyphosate suggested on *Panicum repens* control is 7 liters per hectare applied at the fallow stage to avoid crops injury. However, most of the farmers were not using it, due to its higher price. Therefore, how to decrease the rate of glyphosate and cut down its application cost will be the utmost important work for the time being.

Surfactant Ethokem and AG-F at 0.1 to 0.35% (v/v) added into 3 or 4 liters of glyphosate gave excellent and equal percent control on *Panicum repens*. The time of reaction and duration of control did not show any difference comparing with the chemical applied alone at 7 liters per hectare. (Yeh, H. J., and Chiu, Y. M.)

The Effect of Primextra on Weed Control and Sugarcane Growth

The experiment was conducted in 1979 and 1980 for the purpose of selecting new herbicides to meet the mechanical application on sugarcane fields. Due to the industrialization in Taiwan in recent decades, many labors in agriculture sector have been transferred from fields to factories. For labor saving, herbicidal application had also changed from knapsack to tractor mounted sprayer. Because of the uncomplete stirring and lower solubility of wettable powder herbicides such as diuron, atrazine, and ametryn are not easily dissolved in water. In the meantime, wettable powder always caused cloggy problem during the application. This clogging not only affects the efficacy of weed control but also the quality of spraying work.

One flowable herbicide, Primextra (Dual mixes with atrazine at 2:1 ratio) is selected for pre-emergence application. This herbicide at 2 kg ai/ha has excellent percent control in two experiments on sugarcane fields. Moreover, Primextra can kill some grass weeds such as *Dactyloctenium aegyptium* and *Cenchrus* spp. etc. which are not effectively controlled by atrazine. Comparing the efficacy of weed control with common used herbicides atrazine or diuron both at 1.6 kg ai/ha, Primextra showed much efficacy under the rate of 2.0 kg ai/ha. The number of tillers and plant height of sugarcane were not affected by Primextra. The important point is that the cloggy problem was never happened during the experiments and demonstration plots both on knapsack and tractor mounted sprayer. It is expected that Primextra may substitute the role of atrazine or diuron on weed control in sugarcane fields in the coming future. (Yeh, H. J.)

Irrigation and Drainage

Water Consumption and Irrigation Requirement of Sugarcane

In view of the past nine crop years' records from the studies using lysimeter equipped with automatic mobile shelter and neutron probe, as well as field experiments during the years 1974–83, it was estimated that the total amount of water consumed by one high-yielding cane crop was 1,200–1,300 mm per hectare on medium-textured soil in Tainan, from which about 300 mm was supplied by capillary moisture, 405 mm from effective rainfall, and 400–500 mm from irrigation. The three sources of supply could virtually compensate for each other in contributing to the total consumption.

Therefore, the water requirement, i.e. the actual evapotranspiration for one cane crop with the highest cane yield per hectare and water use efficiency would amount to about 1,200–1,300 mm. Thus, a cane yield of 100 kg will be attained for each mm of evapotranspiration per hectare. Under such conditions, a pan ratio of about 0.8 is obtained by comparing the total amount of water consumed with class a pan evaporation. Meantime, for a low-yielding cane crop, its evapotranspiration is about 900 mm and the water use efficiency is lower than that of a high-yielding crop.

In order to promote the efficiency of irrigation, it is appropriate to apply these results obtained with reference to effective rainfall and capillary water supply. As it is estimated that the efficiency of furrow irrigation on medium-textured soil is about 60%, thus, water required for such farm irrigation will be about 800 mm, while on coarse-textured soil, owing to the negligible of capillary supply of water, the irrigation water required could be twofold of that on medium-textured soils. (Chang, Y. T., and Wang, P. L.)

Leaching of a Saline-Sodic Soil

A leaching experiment was conducted on saline-sodic soil at Ao-Ku plantation, Suantou Sugar Mill. It was carried out using concentric cylinders with diameter 40 cm for measuring the infiltration rate. The cylinders were pressed into the soil for about 10 cm and filled with water at a level of 16 cm.

Desalinization proceeds rapidly under leaching. After leaching of four months, the electric conductivity of saturation extract was decreased from 41.35 mmhos/cm to 4 mmhos/cm. Changes in soil pH values during the leaching period were small. They fluctuated around 8.0 but were never higher than 8.5. Although the sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) of the soil before leaching were very high, the soil was still saline in nature because it contained a large amount of lime. For this reason, both SAR and ESP decreased simultaneously with the

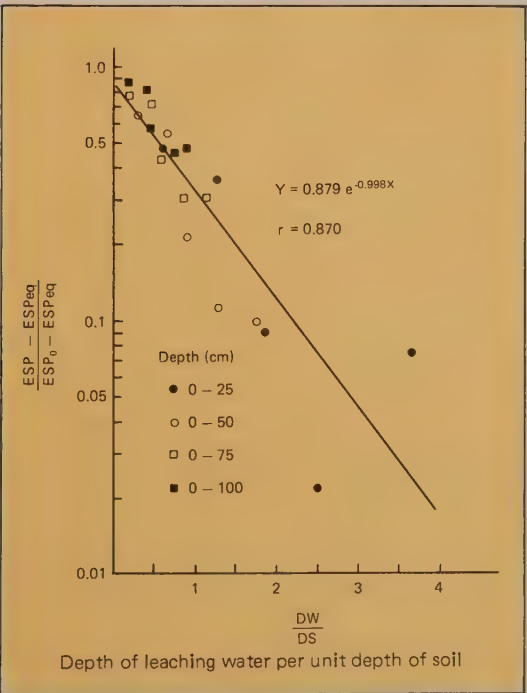


Fig. 13. Desodification leaching curves.

decrease of salt content during the leaching process. From the desodification leaching curve (Fig. 13), it is concluded that in reclamation of the saline soil there is no need of any amendment such as applications of gypsum or lime, mainly because Ca^{++} and Mg^{++} present in the soil were adequate to replace the initial high exchangeable sodium during leaching.

Different theoretical models were tested by comparing the calculated and experimental leaching fractions. The results indicated that theoretical leaching fractions were in good agreement with field data actually observed.

It showed that Dieleman's model is most satisfactory for predicting the amount of water needed for amelioration and salt removal from medium-textured soil during leaching (Fig. 14). (Wang, P. L., Yang, P. C., Chang, Y. T., and Yao, T. P.)

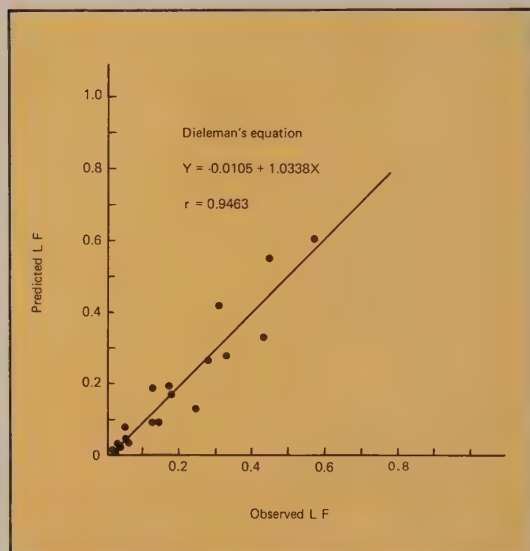


Fig. 14. Comparison of predicted and observed leaching fractions.

Acid Treatment for Well Incrustation

The well incrustation caused by iron bacteria decreases well yield and reduces pump capacity. Iron bacteria can change

dissolved iron to insoluble iron, and produces slime and plug formation in the vicinity of a pumping well. The cleaning work is commonly required as the yield capacity of well has considerably decreased. Iron hydroxides and oxides are quite soluble in hydrochloric acid and sulfamic acid. The quantity of acid added is calculated on the basis of the amount of water standing in the well. The commercial hydrochloric acid (36% concentration) dosage should be in the proportion up to 6 per cent by volume. The scale produced by iron bacteria can be easily dissolved with the acid treatment for 24–36 hrs. But it is difficult to be dissolved when pH value is raised higher than 2.5. A suitable inhibitor is usually employed in the acid treatment. The inhibitor serves to slow down the tendency of the acid to attack the steel well casing, and thus prevents serious damage to the pipe during the course of treatment. The inhibitors Sanhibit-H and Busperse 47 are suitable for use in the hydrochloric acid treatment of wells.

Two methods of acid treatment are recommended for TSC wells:

(1) Cycling pumping method — Guide the pumped water flow back into the well and form a cycling flow during continuously pumping. Then, acid and inhibitor were added into this cycle flow. The flow cycling serves as mechanical agitation of the acid. It is unnecessary to remove the pump, column pipe and the well house as the treatment is in operation. It also does not require to use heavy well drilling equipment. The cost of this treatment method is very low comparing with other methods.

(2) Plug surging method — In use of this method, the pump, column pipe, and well house should be temporarily removed for conveniently installing the surging tools, and the drilling equipment is also required. Thus, it is more expensive than the former one. It is suggested that for a better maintenance program, if the well yield capacity

Table 7. Effect of acid treatment on recovery of original yield of TSC wells by cycling pumping method

Well no.	Well yield (CMH)			Recovery, %
	Original	Before treatment	After treatment	
No. 13	22	13	20	91
No. 16	34	13.3	19.6	58
No. 18	23	12.6	23	100
No. 21	30	10.8	31	103

was not sufficiently recovered by the cycling pumping method, the plug surging method was needed to apply. (Chyou, M. S., and Cheng, C. F.)

Development of Syphon Well

The newly developed syphon multiple well was found more efficient for pumping the ground water and expanding the ground-water use in shallow fine sand aquifer. The main features of the design are described as follows: (1) Several collecting wells are built on a straight line spread from 200 to 300 m long and 20 m apart each; (2) The collecting wells are connected to the main well with pipe lines to form a syphon system; (3) A vacuum pump is connected to the syphon summits to pump out the air in the pipe line to induce syphon action; (4) The connecting pipes can be buried at a depth of 4 m to make the pumping water level drop down to about 13 m for increasing the yield of syphon well.

The advantages of the syphon well, in general, are described below: (1) The construction cost is lower than the conventional wells based on equal well yield; (2) The yield of syphon well can be increased to two or three times than that of the conventional well; (3) The pumping cost is low because the total lifting height will be within 20 m.

The pilot project of 16 syphon wells

was completed in July 1981 at Sah-luen farm and the yields of wells are all very satisfactory. (Fang, Y. T., Chen, C. F., Huang, T. S., and Chyou, M. S.)

Soil and Plant Nutrition

Nitrogen Fixing Blue-green Algae in Taiwan Sugarcane Fields

Distribution of blue-green algae in the soils of southern Taiwan was surveyed in this study. It showed that *Anabaena* spp. and *Nostoc* spp. were the most common heterocystous N-fixing algae, while *Oscillatoria* spp. were the non-heterocystous ones (Table 8). *Anabaena* spp. were found to possess high nitrogen fixing ability in terms of acetylene reduction activity (ARA). The ARA in *Anabaena* spp. and *Nostoc* spp. was higher than that of *Oscillatoria* spp. Pot experiments indicated that soil inoculated with *Anabaena* spp. (1–31) at the rate of 100 ml per pot resulted in 33% increase in cane yield as compared with the check without application of nitrogen fertilizer. However, the cane yield was still 58% less than that of normal level of nitrogen application. No significant increase in total nitrogen content was observed in the inoculated soil. The results revealed that the amount of nitrogen fixed by blue-green algae was not sufficient for the whole stage

Table 8. The dominant blue-green algae in the soils of southern Taiwan

Location	No. of soil samples taken	Dominant blue-green algae genera
Tainan	74	<i>Anabaena</i> , <i>Oscillatoria</i> , <i>Nostoc</i> , <i>Hapalosiphon</i> , <i>Lyngbya</i> , <i>Gloeotrichia</i> .
Pingtung	18	<i>Oscillatoria</i> , <i>Anabaena</i> .
Kaohsiung	24	<i>Oscillatoria</i> , <i>Nostoc</i> , <i>Microcystis</i> .
Yunlin	14	<i>Oscillatoria</i> , <i>Synechocystis</i> , <i>Anabaena</i> , <i>Nostoc</i> .
Changhua	19	<i>Oscillatoria</i> , <i>Anabaena</i> .
Taichung	9	<i>Oscillatoria</i> , <i>Nostoc</i> , <i>Anabaena</i> , <i>Lyngbya</i> .
Nantou	8	<i>Oscillatoria</i> , <i>Nostoc</i> .
Chiayi	16	<i>Nostoc</i> , <i>Oscillatoria</i> , <i>Anabaena</i> .

growth of sugarcane. (Chang, C. H., Huang, C. M., and Wang, C. C.)

Production of Nitrogen Fixing Blue-green Algae in a Jar Fermentor

The production of a potent nitrogen fixing blue-green algae, A-R-6, has been carried out in a jar fermentor. The addition of adequate amount of trace elements, such as copper, manganese, cobalt, and zinc, in the medium was necessary for the good growth of the cells. Sucrose or acetate could be used as the carbon source while it would inhibit the cell growth when its concentration was higher than 600 ppm. When the optimum medium, obtained in the previous

year, was used to produce the algal cells, it showed that the maximum and average specific growth rates (μ_m & μ_{ave}) were 0.82 day^{-1} and 0.42 day^{-1} , respectively, if nitrogen source was added; while 0.59 day^{-1} and 0.33 day^{-1} , respectively, were obtained without the addition of nitrogen source. The optimum temperature for the cell growth was 25° C . The maximum cell concentration was 480 mg/l . (Chuang, Y. T.)

Association of Sugarcane Root and Nitrogen Fixing Bacteria

Beijerinckia indica has been isolated from sugarcane rhizosphere in Taiwan. Its nitrogen fixation ability reached 68.1 and

Table 9. Sugarcane growth affected by nitrogen fixer, *Beijerinckia indica*, associated with the roots

Treatment*	Water culture				Sand culture			
	Plant height (cm)	Dry wt. (g/pot)	Population (#/g root)	Total N in tissue (mg)	Plant height (cm)	Dry wt. (g/pot)	Population (#/g root)	Total N in tissue (mg)
N ₀	70.4 (41)	6.33 (19)	ND**	39.5	50.8 (48)	1.64 (15)	ND	14.2
N ₀ + B	137.6 (77)	21.83 (65)	8.6×10^5	160.7	68.8 (66)	6.03 (54)	3.1×10^4	44.6
N	178.0 (100)	33.51 (100)	ND	543.7	104.8 (100)	11.15 (100)	ND	66.9

* N₀: Nitrogen free; N₀+B: Nitrogen free, inoculated with *Beijerinckia indica*; N: Hoagland solution in water culture, 200 kg N/ha in sand culture.

** ND: Not detectable.



Fig. 15. Sugarcane growth affected by nitrogen fixer, *Beijerinckia indica*.

403 nmoles C_2H_4 /g root hr, as it was associated with sugarcane roots in water and sand cultures, respectively. From the dry weight of sugarcane, it showed that the fixed nitrogen supplied up to 54–65% of the total nitrogen needed for the normal cane growth. Although most of the fixed nitrogen was left in water culture medium (6.9 g N/pot) and leached off in sand culture, an appropriate amount of nitrogen was uptaken in the tissue (Table 9). It is a fact of interest that most of the nitrogen fixers firmly adhered to the sugarcane roots up to 8.6×10^5 and 3.1×10^4 per gram root in water and sand culture, respectively, made no harm to the root (Fig. 15). Almost none of those bacteria were detectable in the water culture medium and sand. (Li, S. W., and Liu, W. C.)

Nutrient Recycling of Hog Manure

Large scale trials were conducted on sugarcane soils of three textures, sandy loam, silty loam and silty clay, to evaluate the utility of nutrient recycling of hog manure. Recommended amounts of N and K

have been partially or totally replaced by hog manure in the treatments. Tissue analyses showed that there was no P and K deficiency on plots irrigated with swine waste slurry whether chemical fertilizer was applied or not. Nitrogen deficiency had been observed on few plots where chemical fertilizer was insufficiently supplemented by hog manure. The highest yield was obtained at the optimum rate of N fertilization in spite of N sources coming from chemical fertilizer or manure. Practically, 40 to 50% of manure NH_4 -N was counted as chemical fertilizer equivalent. This conversion factor of fertilizer value was found to be in accordance with soils of fine to coarse textures. Under good irrigation management, up to 75% of chemical fertilizers could be saved by application of hog manure during the boom stage of sugarcane. (Yen, S. C.)

Prediction of Cane Yield by Equilibrated Soil Potassium Concentration

Results of long term K field experiments can be used to interpret cane yield prediction. Average cane yield at the 300 kg

K₂O/ha plot of the long term experiments in 1963–1979 has been used as the highest yield index (100%). Five grams of soil was equilibrated with 50 ml 0.01 M CaCl₂ to extract K in solution. It was found that the relative cane yield in % was highly correlated with K concentration in equilibrium solution ($r = 0.9734$). From Fig. 16, soil solution containing 8.9 ppm of extractable K would be sufficient to sustain maximum

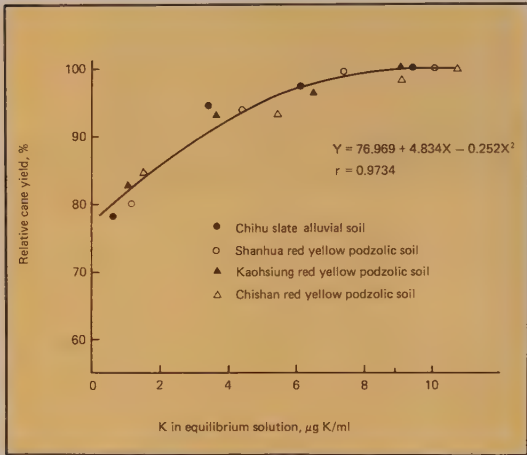


Fig. 16. Relationship between relative cane yield and soil K concentration in equilibrium.

cane growth in terms of soil fertility. On the other hand, cane yield could be estimated by determining equilibrated soil potassium concentration on using the equation of $Y = 76.969 + 4.834X - 0.252X^2$, where Y = relative cane yield, %; X = K in equilibrium solution, $\mu\text{g K/ml}$. (Fang, I. J., and Wang, C. C.)

Liquid Mixed Fertilizer Application on Autumn Planting Canes

Liquid mixed fertilizer used in this study contained 25% of $\text{NH}_4\text{-N}$ and 75% of urea-N for basal dressing. Results from field experiments on medium textured soil showed that the difference in yields of cane and sugar between applications of common solid fertilizer and liquid mixed fertilizer was

not significant. But from rhizotron experiments it indicated that liquid mixed fertilizer application gave a lower yield compared with solid fertilizer application on coarse textured soil, whereas no significant difference was found on medium or fine textured soils. From the nitrogen analyses of different soil horizons, it indicated that leaching effect on the fine textured soil did not cause significant loss of nutrients. (Chan, Y. Y., Weng, T. H., and Wang, C. C.)

The Efficiency of Nitrogen Fertilizer Traced by Isotope ^{15}N

Labelled nitrogen fertilizer ($^{15}\text{NH}_4$)₂SO₄ was applied to autumn planting canes to study the fate of nitrogen in soil. Results of pot tests in Table 10 indicated that the amount of nitrogen taken up from the fertilizer by cane plants (above-ground) of the

Table 10. Uptake of fertilizer nitrogen by different cane varieties determined through ^{15}N -techniques

Variety	Fertilizer N utilized, in %	N required for fresh cane, g/kg cane	Fertilizer N to soil N ratio in tissue
F160	22.3	1.53	1:12
ROC 1	28.1	1.15	1:12
ROC 4	36.9	1.58	1:7

tested varieties was in the following order: ROC 4 > ROC 1 > F160. However, ROC 1 was the lowest in nitrogen requirement per unit fresh cane. It might be related to its early maturity in nature. The ratio of fertilizer-N to soil-N absorbed by autumn canes ranged from 1:7 to 1:12. It indicated that around 87–92% of the total N in plants was taken from the soil nitrogen source in autumn planting canes. (Chan, Y. Y., and Weng, T. H.)

Plant Pathology

Resistance of New Clones and Foreign Varieties to Major Diseases

1. Downy mildew

In 1982–83, a total of 293 new clones developed at our Institute and 80 varieties from Fiji, Hawaii and Louisiana were tested for their resistance to downy mildew at Nantou Downy Mildew Testing Nursery. Moderate to high level of resistance to the disease were found in 71.7% of the new clones and 85.0% of the foreign varieties tested

(Table 11). Sugarcane varieites from Hawaii appeared to be more susceptible to downy mildew, and H69-3971, H70-3339, H71-1476 and H71-3702 were highly susceptible to the disease.

2. Smut

Two experiments were conducted at Suchongshi Smut Testing Nursery for determining reaction of 191 new clones, 86 foreign varieties, and 68 parental varieties to the smut disease of Race 1. The 1-bud seed pieces of each clone and variety was inoculated by pin-pricking method before planting. The results indicate that 39.6% of the

Table 11. Reaction of new clones and foreign varieties to downy mildew (spring planting)

Level of resistance	No. of varieties from		Check variety	Percent infection
	Taiwan	Foreign countries		
Highly resistant	43 (14.7%)	30 (37.5%)	F108	0.5
Resistant	37 (12.6%)	10 (12.5%)	NCo310	0.5
Moderate	130 (44.4%)	28 (35.0%)	F134	5.8
Susceptible	64 (21.8%)	8 (10.0%)	H44-3098	14.4
Highly susceptible	19 (6.5%)	4 (5.0%)	PT43-52	31.7

Table 12. Reaction of Taiwan and foreign varieties to leaf blight and leaf scorch

Level of resistance*	Leaf blight				Leaf scorch			
	No. of varieties from**				No. of varieties from**			
	T	F	H	L	T	F	H	L
0	16	3	0	0	—	—	—	—
1	1	0	0	0	5	1	0	0
3	1	0	1	0	12	4	0	0
5	5	2	5	1	10	8	3	0
7	8	12	8	1	5	15	14	2
9	4	13	8	0	3	1	4	0

* 0: hypersensitive, 1: highly resistant, 3: resistant, 5: moderate, 7: susceptible, 9: highly susceptible.
** T: Taiwan, F: Fiji, H: Hawaii, L: Louisiana.

new clones and 62.7% of the foreign varieties tested showed moderate to high level of resistance to smut. Six new clones and 14 foreign varieties (CP63-588, M1516/66, H65-4174, H69-227, H70-2329, H71-2464, H71-3702, H72-6089, H72-6317, H73-6136, LF70-1699, LF70-2023, LF70-2806, and Mana77-111) were highly resistant to the disease.

3. Leaf blight and leaf scorch

The reaction of 35 new clones and 54 foreign varieties to leaf blight and leaf scorch was determined by artificial inoculation. The results obtained are shown in Table 12. Hypersensitive reaction to leaf blight was found in 16 new clones and 3 Fijian varieties.

4. Rust

Field surveys revealed that the incidence of sugarcane rust caused by *Puccinia melanocephala* reached the peak in March to June, then declined rapidly in July and became very rare in September and thereafter. The first peak occurrence of *P. kuehnii* was found in February to March and another peak in June to August. The number of uredospores produced per unit area of lesion per day was generally lower on the resistant varieties. (Lee, C. S., Wang, Z. N., and Fang, J. G.)

Stem Rot of Sugarcane in Taiwan

The stem rot of sugarcane caused by *Gibberella moniliformis* (Sheldon) Wine-land was first found in the varieties F160, ROC 1 and ROC 5 in the southern part of Taiwan in the summer of 1982. However, no further spread of the disease was observed. The internal tissue of an infected stem showed the typical dirty reddish symptoms (Fig. 17). The isolates from the lesions consistently yielded *Fusarium moniliforme* (conidial state of *G. moniliformis*, Fig. 18), and the typical symptoms appeared in the

stem 2 to 3 weeks after artificial inoculation of conidia. Reaction of 42 sugarcane varieties to the disease was also determined (Table 13). Most of the varieties tested were resistant and moderately resistant to the disease. (Wang, Z. N.)



Fig. 17. Stem rot symptoms appearing in the upper portion of cane stalks.

Table 13. Reaction of sugarcane varieties to stem rot caused by *Gibberella moniliformis*

Variety	Reaction*	Variety	Reaction*
F141	1	F168	7
F145	5	F169	3
F146	1	F170	3
F147	1	F171	5
F148	1	F172	1
F152	5	F173	7
F153	7	F174	5
F154	7	F175	5
F155	5	F176	7
F156	3	F177	5
F157	1	F178	5
F158	7	ROC 1	9
F159	7	ROC 2	1
F160	5	ROC 3	3
F161	1	ROC 4	1
F162	1	ROC 5	9
F163	3	71-91	1
F164	5	71-322	1
F165	7	71-4053	1
F166	5	71-5187	1
F167	5	NCo310	3

* 1: highly resistant; 3: resistant; 5: moderate; 7: susceptible; 9: highly susceptible.

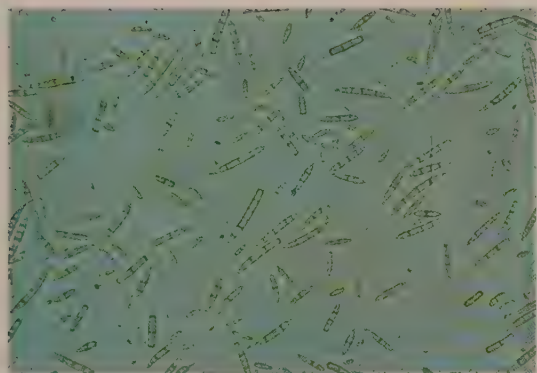


Fig. 18. The conidia of *Fusarium moniliforme*.

Induction of Perfect State of Root and Basal Stem Rot of Sugarcane

Nutritional induction of the perfect state of *Xylaria* sp., the causal organism of the root and basal stem rot of sugarcane, was studied by using 7 different culture media. The media tested included potato dextrose agar (PDA), tannic acid agar (TAA), Leonian's agar + 2% yeast extract (LYA), commercial malt extract agar (CMMY), and three different formulations of malt extract agar (MEA-I, -II, -III). The fungus was cultured on the different media at 26° C, and the development of colonies and the formation of stromata were examined 4 weeks after incubation. The stromata bearing conidia were produced on the surface of PDA, LYA, MEA-II and MEA-III (Fig. 19). However,



Fig. 19. Development of *Xylaria* sp. on different media 4 weeks after incubation at 26° C.

all of the media used failed to induce the formation of the perfect state of *Xylaria* sp.

Young roots of sugarcane, rice, wheat, corn and sorghum were artificially inoculated by contact with the mycelium-colonized mango twigs. The roots were removed periodically, cleared, stained, and hyphal penetration into root cells was observed under microscope. No hyphal penetration was found except in sugarcane roots (Fig. 20). Generally, the mycelia colonized in sugarcane root cells 7 days after inoculation, and 3 months later, they spread into the internal tissue of seed-pieces. (Fang, J. G., and Lee, C. S.)

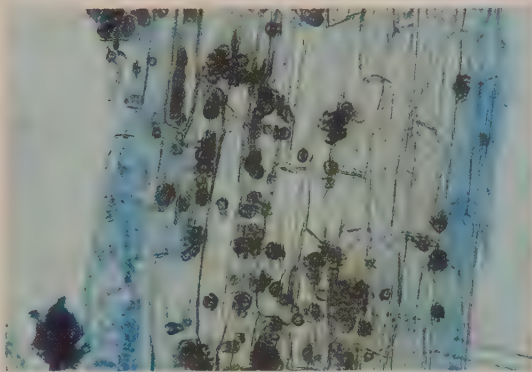


Fig. 20. Colonization of the mycelia of *Xylaria* sp. in the cells of young sugarcane roots.

Comparative Studies on Diagnosis of Ratoon Stunting Disease

Ratoon stunting disease (RSD) is one of the most important disease of sugarcane in the world. RSD does not show specific external symptoms, and the internal symptoms of red discoloration in the vascular bundles of cane stalks are the only basis for field diagnosis of the disease. However, the expression of internal symptoms often varies with varieties, physiological and climatic conditions, causing some difficulty in identification of RSD in the field.

The incidence of RSD in 7 varieties NCo310, F146, F160, F177, ROC 1, ROC 4 and 71-6063 was investigated at Hsingying during October 1982 to February 1983.

One hundred stalks were taken from the plants of more than 12 months old for each variety, and examined for the presence or absence of the internal symptoms. Then, the fibrovascular sap extracted from the cuttings of diseased and symptomless stalks was examined under dark field microscope (800 x).

The presence of coryneform bacteria was detected in every stalk showing RSD symptoms. However, the bacteria were also found in 8.6 to 55.4% of the symptomless stalks of the different varieties. The results seem to suggest that some varieties might be a symptomless carrier of RSD. Development of more rapid and precise method for diagnosis of RSD is also needed. (Wang, C. S., Jiang, D. K., and Chen, C. T.)

Control of Sugarcane Root-Knot Nematode with Resistant Crops and the Effect of Nematode and Soil Fungus Infections on Sugarcane Growth

Field experiment was again conducted in 1982–83 to determine the efficacy of growing nematode-resistant crops in sugarcane field for suppressing the occurrence of sugarcane root-knot nematode (*Meloidogyne incognita*). The resistant crops, sunhemp (*Crotalaria juncea* L.) and peanut (cultivar Tainan No. 9), were planted in the field 5 months before planting of sugarcane (variety F160). These treatments gave 17.4 to 28.6% increases in cane yield when compared with that of check treatment, 5-month fallowing. However, the effect was still inferior to that of preplanting application of Counter granules at the rate of 3 kg a.i./ha.

It was also found that inoculation of the root-knot nematode and *Penicillium* sp., *Pythium* sp., or *Ceratocystis* sp. in the soil resulted in more severe damage on roots and retarded growth of the young plants of F160 (Fig. 21). Further studies will be made on the occurrence of soil fungi in sandy and sandy loam soils and the joint-



Fig. 21. Growth of 3 months old plants of F160 on the soil inoculated with the root-knot nematode and *Pythium* sp. From right to left: CK; soil inoculated with *Pythium* sp.; with nematodes; and with both.

effect of parasitic nematodes and soil fungi on sugarcane growth. (Hu, C. H., and Tsai, T. K.)

Entomology

Studies on the Natural Enemies of Sugarcane Insect Pests

In Taiwan, *Trichogramma australicum* Girault has been used as the scientific name for the parasite which parasitizes the eggs of *Argyroplote schistaceana*, *Chilostraea infuscatella*, *Proceras venosatus*, etc., since 1929. Recently, however, the specimen of this egg parasite sent to Taiwan Agriculture Research Institute was identified and confirmed by USDA (HIBII 83-00394) to be *Trichogramma chilonis* Ishii.

Elasmus zehntneri Ferriere (Fig. 22), an ectoparasite of the larval stage of *Scirpophaga nivella*, was recovered again from the cane field. The parasite was propagated in the laboratory for 6 successive generations and its bionomics was studied. Unfortunately, the search for a laboratory host was unsuccessful.



Fig. 22. *Elasmus zehntneri*, an ectoparasite of *Scirpophaga nivella* larvae.

In last crop year, 10 larvae of *Sesamia inferens* (6 more from other samples taken in the same field) parasitized by *Apanteles flavipes* were collected from the survey field. This is the highest number of parasitized hosts ever found in a crop year since the starting of the survey in 1974–75. Besides, 9 *Trichogrammatoidea nana* were trapped with the sterilized eggs of *A. schistaceana* in October 1981. This is the second time, the first in November 1979, that *T. nana* was collected from the cane field.

The susceptibility of sugarcane white grub (*Alissonotum impressicolle* Arrow) to the milky disease (*Bacillus popilliae*) was determined in laboratory experiments. The spore mixture was applied into the soil at the rate of 0.04 gm per pot (9 cm dia.)

before releasing 10 white grubs into each pot. In another experiment, 0.015 ml of the spore suspension (1×10^8 spores/ml) was injected into the mouth part of each grub by means of microinjector, then the grubs were reared in pots containing soil and cane pieces. Examination made 6 weeks later (Table 14) revealed that none of the treated grubs displayed the symptoms of milky disease. It was also found that infection of *Metarrhizium anisopliae* had occurred on some individuals of the grubs. (Cheng, W. Y., and Chang, C. H.)

Development of Sugarcane Woolly Aphid in Relation to Sugarcane Varieties

Laboratory experiment was carried out to determine the effect of sugarcane varieties on the development of sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner. Apterous adults were placed on 5 cm leaf-pieces of F160 floated on a modified Hoagland-Snyder nutrient solution at the rate of 5 adults per leaf-piece and kept at 22° C. The progeny produced was used for the experiment.

Young nymphs of less than 24 hr old were transferred to the leaves of 6-month-old plants of F160, F172, F177 and ROC 1 at the rate of 6 nymphs per leaf, then the plants were placed in a growth chamber

Table 14. Susceptibility of white grub (*Alissonotum impressicolle*) to *Bacillus popilliae*

No. of grubs treated		% survival	% mortality					% escape	
			Milky disease	<i>Metarrhizium anisopliae</i>	Unknown disease	Other causes	Total		
Injection test									
CK	60	50.0	0.0	5.0	21.7	0.0	26.7	23.3	
Treated	60	46.7	0.0	6.7	5.0	8.3	20.0	33.3	
Feeding test									
CK	60	38.3	0.0	21.7	1.7	1.7	25.1	36.7	
Treated	120	39.1	0.0	4.2	2.5	9.2	15.9	45.0	

Table 15. Effect of sugarcane varieties on the development of *Ceratovacuna lanigera*

Variety	Nymphal stage, days	Adult stage, days			Progeny/adult
		Reproduction stage	Postreproduction stage	Total	
F160	18.0 a	38.5	6.8	45.3 ab	117.3 a
F172	19.0 a	29.5	3.0	32.5 b	76.5 a
F177	19.9 a	40.7	16.9	57.6 a	109.2 a
ROC 1	25.0 b	39.0	1.0	40.0 ab	17.0 b

Means not followed by the same letter differ significantly at 1% level.

maintaining a temperature of 22° C and 16 hr photoperiod. Establishment of the nymphs on different varieties was investigated 5 days after nymphal introduction, and not more than 2 nymphs were allowed to feed on a same leaf. The period of nymphal stage, the first date of reproduction, and the number of progenies produced were recorded for each individual.

As shown in Table 15, ROC 1 appeared to have adverse effects on the development of *C. lanigera*. Rearing of the aphid on ROC 1 resulted in prolonged nymphal stage (25.0 days), and the adults produced the lowest number of progenies (17.0/adult). The adult fecundity was also affected to some extents when the aphid was reared of F172. Field surveys revealed that the aphid densities on ROC 1 and F172 were consistently lower than that on F160 and F177. Studies on the mechanisms of varietal resistance to *C. lanigera* are now in progress. (Pan, Y. S., and Yang, L. S.)

Occurrence of Sugarcane Mosaic and Vector Aphids in Hualien

Sugarcane mosaic again tends to become a problem in Hualien district in recent years. A field experiment was carried out at Tafu Farm, Hualien Sugar Mill, to investigate the infection of sugarcane mosaic on different varieties and also the occurrence of

vector aphids. Five varieties were planted in plots with 4 replications in a completely randomized block design on August 19, 1982. First survey of the disease incidence on the 5 varieties was made 2 months after planting, then 6 surveys were conducted at an interval of 1 month. The newly infected plants found in each survey were marked. A yellow-pan trap was placed in each plot of the middle 2 replications 1 month after planting of sugarcane. The species and the number of aphids trapped were examined every day throughout the period of experiment.

As shown in Table 16, 54.1 to 64.2% of the aphids trapped during September 1982 to March 1983 were the vectors of sugarcane mosaic virus. Severe infection of the disease occurred on F177, F178 and 73-2644, and 74.2 to 88.7% of the young plants

Table 16. Percent infection of sugarcane mosaic on different varieties in Hualien

Variety	% vector aphids trapped	% infection
F160	58.8	0
F177	54.5	88.7
F178	64.2	74.2
ROC 1	61.5	0
73-2644	54.1	74.0

of the 3 varieties were infected. Although the percentages of vector aphids trapped in F160 and ROC 1 plots were higher than that in F177, no infection of the disease was found on the 2 resistant varieties.

Field experiments conducted at Tainan in 1981–82 indicated that percent vector aphids collected did not differ significantly among the different varieties, and only 6.7 and 8.5% infection of sugarcane mosaic occurred on F178 and F177. Whether the severe occurrence of the disease on these two varieties in Hualien is due to development of a new strain, or the vector aphids in the area are more efficient in transmitting sugarcane mosaic virus, still remains to be clarified. (Yang, S. L., and Chen, C. T.)

A Preliminary Study on Trap Crops for *Anomala expansa*

Bozelle (*Hibiscus sabdariffa* L.) plants were found to be attractive to the adults of *Anomala expansa*. During the period of adult emergence in June to November, a considerable number of adults was attracted to bozelle plants planted in the edge of sugarcane field, and 7.3 adults were collected per plant per day. Of the adults collected, 49% of the individuals were the females possessing an average of 33.6 eggs in their ovaries. The adults mated on bozelle plants, then dispersed. More studies are needed to determine whether the bozelle plants could be used as a trap crop for *A. expansa*. (Hsieh, S. A., and Chang, C. H.)

Laboratory Evaluation of New Rodenticides

Toxicity of Bromadiolone and Silmurin (Scillirocide) baits to the wild rats damaging sugarcane was determined in the laboratory. All of the individuals of *Rattus losea* fed 0.005% Bromadiolone bait for 1 day died within 6.3 days. The treatment, however, caused 50.0 to 61.5% mortalities in *Bandicota nemorivaga*, and 100% mortality was

observed only when the rats were fed 0.005% bait for 3 days.

On the other hand, 100% mortality occurred in *B. nemorivaga* when the individuals were fed 0.01% or 0.025% Silmuring bait for 1 day. The bait was very often rejected by *R. losea* and *R. norvegicus*, resulting in a lower mortality. Only 12.5% of the individuals of *Apodemus agrarius* died even they were fed 0.025% bait for 7 successive days. These results indicate that the toxicity of Bromadiolone and Silmurin baits to the wild rats is more specific. (Wang, P. Y.)

Sugar Technology

A Factory Trial on Continuous Sugar Boiling

For quite a few years efforts have been directed towards the conversion of the present batch method of sugar boiling to a continuous process. The conventional calandria pan of 340 HL at Matow Sugar Factory was divided into four compartments as four stages of continuous sugar boiling system. The seed magma was currently introduced by metering pump into the first compartment of the pan, and the massecuite was flowed through compartments to the exit of the last compartment by overflow. The supersaturation of mother liquor was kept constant through the feeding of runoff into each compartment and the evaporation of the corresponding water. The pan was fitted with an automatic control system including pressure control in the calandria, vacuum control in the vapor pipe, and intermediate conductivity control. The operation could be easily handled, and released from need of skilled sugar boilers. The low grade massecuites (58% purity) could be centrifuged without difficulty by a CV 0.31 and a mean aperture of 0.27 mm. The recovery was as good as that of batch

operation. (Cheng, H. T., Chen, C. H., and Hsieh, T. P.)

Cane Juice Decolorization by Ultrafiltration

Ultrafiltration is a separation process being introduced into a large number of industries. In order to find out how valuable it might be for the sugar industry, ultrafiltration was studied to remove the color from the clarified juice during 1982/1983 campaign. Three membranes of molecular weight cut-off 20,000, 100,000 and 300,000 were investigated. The heat resistant and pH stable membrane GR61P was suitable for the clarified cane juice decolorization. Passing the clarified juice of sulfitation through an ultrafilter of GR61P membrane with a molecular weight cut-off of 20,000 resulted in a juice of superior clarity. Sixty to seventy percent of the color matter in juice was eliminated, and the sugar manufactured from the ultrafiltered juice was as good as the plantation white sugar from the conventional carbonation process. Development of commercial thermo- and pH-resistant membrane will enable the application of ultrafiltration for elimination of the color in cane juice. (Cheng, H. T., and Ton, J. F.)

Syrup Clarification for Improving Sugar Quality

Raw syrup impurities, such as insoluble matter, gums and colorants, have a detrimental effect on sugar quality. The removal of these impurities has been attempted in factories producing plantation white sugar, and considered to be possible by using a phosphatation flotation process. The process is based on the technique of forming tricalcium phosphate floc within the syrup and floating off the flocculum with the assistance of air bubble. A system was developed for strict control of the amount of

dissolved air, the size of air bubbles, the addition of reactants, pH and temperature. The pilot plant scale cylindrical flotator of 180 cm in diameter and 210 cm in height was designed. Experimental results showed that the capacity was 9 tons/hr, the retention time of syrup was 30 minutes, and the turbidity of clarified syrup was 7.5, which gave 77% reduction in impurities. The sugar boiled from the clarified syrup showed a substantial improvement in quality. (Cheng, H. T., Chen, C. H., and Ton, J. F.)

Sugar Colorants in Stored Plantation White Sugar

Colorants isolated from the stored plantation white sugar were fractionated by high performance gel permeation chromatography (HpGpC). Spectrophotometric and chromatographic studies indicated that some of the color bearing compounds, such as protocatechuialdehyde, gentisic acid, 2,3-dihydroxybenzoic acid, 3 hydroxybenzoic acid and caffeic acid were responsible for color development during storage. All of these compounds were identified from low molecular weight fraction of HpGpC. Further studies on the other fractions will be made. (Cheng, H. T., and Lin, W. F.)

Production of Sucrose Coconate

An attempt to prepare surface active sucrose coconate by the solvent-free heterogeneous process has been successfully achieved. The rapid thin-layer chromatographic method developed last year was used to separate and identify the components of the sucrose coconate. The yield of sucrose fatty acid esters was 25%. The product contained sucrose fatty acid esters, monoglyceride, diglyceride, triglyceride and potassium soap. It can be used as a safety and biodegrading food grade detergent. (Cheng, H. T., Leu, L. S., and Ting, C. S.)

A Trial on Concentration of Syrup with Falling Film Evaporator

In order to handle the heavy syrup in a very short time, an easy-to-operate and higher heat transfer rate evaporator was developed in 1982–83 campaign. A pilot plant scale falling film evaporator with heating surface of 4.5 M² was designed. The evaporator consists of feed distributor, heat exchange tubes and vapor chamber. The feed distributor is an array of wires for equal distribution of the juice to each tube of the tube bundle. The heat exchange tubes include 18 vertical tubes, 1.9 cm in diameter and 4 m long. The vapor chamber is an enlarged section at the lower end of the tube bundle in which the syrup can be separated from the vapor. This type of evaporator must have a constant supply of syrup to the feed distributor. Therefore, it is necessary to have a flow control. Experimental results showed that the concentration of outlet syrup was easily controlled and rather stable. The overall heat transfer coefficient was increased with the increase of the syrup flow rate. The retention time of the syrup was less than 1 minute, thus the enhancement of colorant content was minimized. Application of the falling film evaporator has the following advantages: capable to handle very high Brix product without crystallization, minimal syrup residence time, eliminating level control problems, and easy in operation. (Chen, C. H., and Chang, R. Y.)

The Grayish Tinge of Sulfitation Plantation White Sugar

When sulfitation sugar is compared with carbonation sugar, it appears less glossy and shows two major differences in spectral characteristics, a higher N value of 100 (A520/A455)² and a higher absorbance at 720 nm. These two spectral variables and the achromatic density (D) of sugar solution were used to estimate the degree of grayness (G)

by the following formula.

$$G = D^a \times N^b \times (A720)^c$$

Where, a, b, c are assigned to unity tentatively.

The G value of sulfitation sugar ranged from 48.4 to 121.6, while in carbonation sugar it was in the range of 10.6 to 55.9. It was possible to differentiate the color quality in sulfitation sugar and carbonation sugar.

In order to improve the color of sugar from sulfitation, the gray causing substance was investigated. The SEM elemental analysis of the sulfitation sugar showed higher o/c and N/c values in suspended solid and also a higher N value in solution. The high molecular weight substances seemed to be the cause of graying in sulfitation sugar.

Most of the high molecular weight substances in sugar are negatively charged. For eliminating these substances, sulfitation raw syrup was passed through column of anionic resin Amberlite IRA-900. The G and N values of effluent syrup decreased drastically. Application of cationic surfactant for raw syrup purification also showed the similar result. For economical improvement of the apparent color of sulfitation sugar, effort should be also made to seek process other than ion exchange decolorization. (Cheng, H. T., and Wang, C. R.)

A Rapid Assessment of Cane Biodeterioration

Assessment of cane biodeterioration was studied for the purpose of routine quality control of canes transported to sugar mills. The method proposed is based on the observation of cane juice turbidity by naked eye as the juice was first partially clarified with modified Herles's reagent. Six turbidity grades were set as parameters for the assessment. The experimental results in Table 17 indicated that the mechanically-harvested canes deteriorated rapidly during storage and significant quality decline was found after

Table 17. Biodeterioration of mechanically-harvested canes

	No. of days stored					
	0 (check)	1	2	3	4	5
Juice Brix	20.8	20.1	20.7	20.4	20.8	20.2
pH	5.2	5.1	5.0**	4.8**	4.7**	4.5**
Dextran (ppm)	600	1,100	3,200**	4,300**	4,400**	5,800**
Pol deviation	-0.2	-0.2	-1.2**	-1.7**	-2.2**	-2.7**
Turbidity grade	1.0	1.0	2.2	3.0	4.0	4.8

** Significantly differed from check at 1% level.

storage of two days. The cane quality was continually declined as the days of storage increased. The turbidity grades as assessed by the proposed method showed a close relation with the incidental conditions of cane deterioration. It appeared to be a rapid and useful indicator on the assessment of cane biodeterioration. (Yeh, C. S.)

By-product Utilization

Production of High Quality Food Yeast

The production of high quality food yeast has been studied. In order to increase the cell concentration of the fermented broth, fed-batch process with various feeding rates were carried out in a 14-litre jar fermentor. Under the optimal condition, the final cell concentration of 68 g/l with the yield of 40% (on total sugar) or 46% (on consumed sugar) was obtained.

The nucleic acid content of the final product could be easily reduced from 7.5% to 3.5% by treating the whole cells with NaCl solution. After the extraction, 86% of yeast with light-color could be recovered. Vitamins content of the yeast cells, however, could not be enhanced remarkably if the medium was enriched with vitamins during

fed-batch cultivation. (Chang, C. Y., Kuo, Y. C., and Wang, L. H.)

Production of Dissolving Pulp from Bagasse

Dissolving pulp could be produced by acid prehydrolysis followed by sulfate cook of the depithed bagasse. Prehydrolysis is essential for removing pentosans if bagasse was used as the raw material. The prehydrolyzed sulfate pulp was then bleached and purified in a CEHDA refining sequence. The characteristics of the pulp thus produced were as follows: alpha-cellulose > 90%, pentosans 2–4%, DP (degree of polymerization) 600–850, brightness 90–92, and ash 0.1–0.3%. The pulp with such properties gave a promise for rayon manufacturing. (Huang, H. C., and Hsieh, W. C.)

Alcohol Fermentation by Immobilized Yeast Cells

The immobilization of yeast cells and its application for the alcohol fermentation have been studied. Na-alginate was selected as the carrier for the immobilization of yeast cells. The growth of the immobilized yeast cells and free cells in molasses medium was compared. The final number of cells per ml gel was higher than that of free cells per ml medium. The specific alcohol productivity

of the immobilized yeast cells preactivated for overnight was about 3 times of that without activation.

The continuous production of alcohol has been carried out in a column packed with the immobilized yeast cells. The molasses medium containing 15% (w/v) sugar was continuously fed in with a retention time of 3.5 hr. The productivity of alcohol was found around 12 g/l/hr. The operation has been maintained steadily for 9 days.

The effect of temperature on the cell growth and alcohol fermentation was also examined with free cells. The results revealed that the higher temperature was, the faster both the cell growth and alcohol fermentation were if the temperature was not higher than 43° C. (Hsie, M. C.)

Isolation of New L-lysine Producing Mutants

The mutants consisted of both nutritional requirement and analog resistance through multi-step mutation, such as Hse⁻.Leu⁻.AEC^r.AspHX^r, Hse⁻.Leu⁻.AEC^r.SD^r, AEC^r.Ala⁻.CCL^r.ML^r, AEC^r.Ala⁻.CCL^r.ML^rFP^s, and AEC^r.Hse⁻.Leu⁻.Pant⁻ of *Corynebacterium* and *Brevibacterium*, have been used in L-lysine fermentation recently. Efforts have been made in this lab to obtain such kind of mutants. Several good L-lysine producers, auxotrophic mutants of *Corynebacterium* sp. other than *Brevibacterium* sp., currently used in our L-lysine plant, were successfully isolated.

Since S-2-aminoethyl-cysteine (AEC, L-lysine analog) strongly inhibits the growth of both wild strains of *Brevibacterium flavum* and *Corynebacterium glutamicum*, a number of AEC^r mutants were isolated from them, and further selection was underway in order to obtain even better L-lysine producers. (Liú, Y. T.)

Improvement of Acid Method for Xylose Production from Bagasse or Bagasse Pith and Utilization of the Residues

Efforts have been made to develop an alternative process for the production of xylose from bagasse or bagasse pith. The raw material mixed with two-fold volume of 1–2% H₂SO₄ was hydrolyzed under high temperature and pressure, then xylose was recovered by counter-current washing. The optimum conditions have been obtained. Although xylose concentration of the hydrolyzate was only around 10% comparing with that of 17% obtained in the previous year, the residual acid content in the final product was very low, ranging 1–2% instead of 17–20% of the previous results. The best recovery of xylose was 70–80%, and 6–10g of xylose could be produced with each gram of acid used. Further studies are underway to increase the xylose concentration by trying out acids other than sulfuric acid.

The feasibility of the production of pulp or/and alpha-cellulose from the residues was investigated. The pulp preparation was unsatisfactory judging from the results of tensile test, bursting test, and tearing test of the paper made from the pulp, while the alpha-cellulose preparation could meet the requirements being used the raw material for manufacturing of rayon. (Yeh, W. F., Sang, S. L., Wang, L. H., Hsie, M. C., and Kuo, Y. C.)

Some Factors Causing Hard Bleaching during Bagasse Pulping

One of the factors causing hard bleaching of the sulfate bagasse pulp was the high content of iron which was mainly transformed from clay in the bagasse during high temperature cooking. The iron content of about 50 ppm could decrease 1.4–2.0 units in
(continued on page 34)

Major Diseases



Sugarcane white leaf disease (Mycoplasma)



Sugarcane mosaic (SCMV-A)



Leaf blight (*Leptosphaeria taiwanensis* Chi)



Ratoon stunting disease (Bacterium)

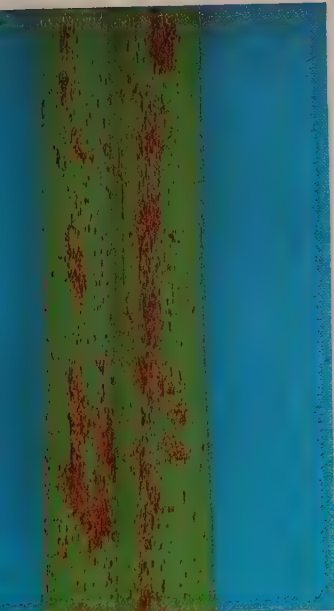


Downy mildew (*Peronosclerospora sacchari* Shirai & Hara)



Smut (*Ustilago scitaminea* Syd.)

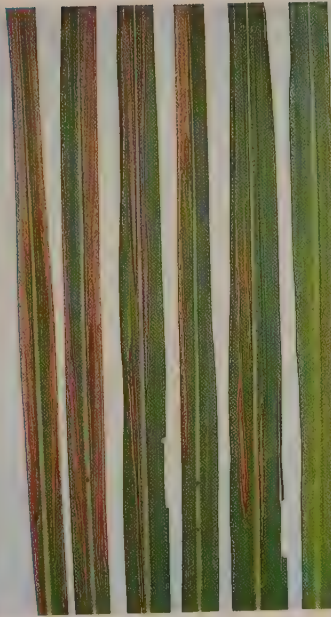
arcane in Taiwan



Puccinia kuehnii (Krüg.) Butl.)



(Puccinia melanocephala Syd.)



Leaf scorch (*Stagonospora sacchari* Lo & Ling)



Brown spot (*Cercospora longipes* Butl.)



Root and basal stem rot (*Xylaria* sp.)



Root and basal stem rot, showing stroma on cane stubble

brightness. The higher the iron content in the bleached pulp was, the greater the brightness reversion was observed. The iron content could be reduced by an acidic washing of unbleached pulp prior to or after the chlorination stage. Therefore, the bleached pulp with the desired brightness could be obtained.

Another factor was an intermixing of the decayed bagasse at the surface layer of the wet storage pile. In case of this kind of bagasse was used as the raw material, the pulp with dark brown color, higher K-number, and lower freeness and physical properties would be produced. As the intermixing of the decayed bagasse was controlled under 10% of the total raw bagasse during digesting, there was no appreciable influence on bleaching and physical properties of the pulp produced. (Hsieh, W. C., and Yang, P. W.)

Disposable Dishes from Bagasse Pulp

The bleached bagasse pulp (430–650 g/m²) was used as the raw material for the production of disposable and sanitary dishes. It was first molded into shaped dishes under heat and pressure, then the surface of the dishes was treated with melamine-formaldehyde resin (10% on the weight of the

molded dishes) or laminated with aluminum foil to reinforce the wetting resistance. The molded dishes could also resist hot water of 80° C if it was treated with food grade waxes of higher melting point.

The molded dishes of pure bleached bagasse pulp are sanitary, strong to retain shape, recoverable as waste pulp, disposable by combustion, and decomposable by landfilling. Therefore, no environmental problems would be occurred from using them. (Hsieh, W. C., and Yang, P. W.)

Improvement of Immobilization of 5'-phosphodiesterase

The improvement of the immobilization of 5'-phosphodiesterase for the production of 5'-nucleotides from ribonucleic acid (RNA) has been studied. Crab shell chitin pretreated with Y-aminopropyltriethoxy silane was used as the support for the immobilization of 5'-phosphodiesterase. The temperature and pH optima for the immobilized enzyme were found similar to that of the free one. The immobilized enzyme showed a half-life of 7 days in a packed column system operating at 55° C and pH 5.0 with 3% substrate concentration at a flow rate of 3 space velocity. (Lai, C. L.)

Research on Sugarcane Diseases and Insect Pests in Taiwan

Y. S. Pan

Abstract

This paper presents a review of progress in the research of sugarcane diseases and insect pests in Taiwan during the past 30 years. Fundamental studies on the causal organisms of major diseases and host-pathogene relationships have led to the development of extensive program of screening new clones and varieties for resistance to the major diseases. The incidence of sugarcane mosaic, downy mildew (*Peronosclerospora sacchari* Shirai & Hara), red rot (*Physalospora tacumanensis* Speg.), smut (*Ustilago scitaminea* Syd.), and leaf scorch (*Stagonospora sacchari* Lo & Lin) has been suppressed to a very low level with the use of resistant varieties and periodical inspections of sugarcane nurseries. The nature of the causal agent and the insect vector of white leaf disease were clarified, and spring planting of sugarcane was recommended for control of the disease. Effective control of sugarcane root-knot nematode (*Meloidogyne incognita* Chitwood) in sandy soil has been obtained with preplanting application of Counter or Terracur P granules.

Of the 16 species of parasites introduced into Taiwan during the past 27 years, the establishment of *Isotima javensis* Rohver was proved. Periodical release of *Trichogramma australicum* Girault at a rate of 100,500/ha during a period of 7 to 10 months resulted in 54.3% decrease in larval infestations of *Tetramoera schistaceana* Snell., *Proceras venosatus* Walker and *Chilotraea infuscatella* (Snell.) Kapur on the internodes of mature cane. Considerable increase in percent parasitisms of the nymphs of *Mogannia hebes*

Walker by *Isaria sinclairii* (Berk) Lloyd and *Metarhizium anisopliae* (Metch) Sor. was obtained after the release of these fungi in the soil at the rate of 100 cultural flasks/ha. Mechanisms of sugarcane resistance to *T. schistaceana* was studied, and seedling evaluation was found to be feasible for screening sugarcane germ plasma for resistance to the moth borer. Economic thresholds were established for the sugarcane white grubs (*Alissonotum impressicollae* Arrow) and sugarcane wireworm (*Melanotus tamsuyensis* Bates). Preplanting application of Thimet, Terracur P or Counter followed by side-dressing 4 to 6 months after planting of sugarcane was recommended for control of these soil insects. Effective control of wild rats in sugarcane fields was obtained with application of 0.005% Klerat baits at the rate of 1–2 kg/ha during October to March.

Introduction

Sugarcane (*Saccharum officinarum* L.) is one of the most important industrial crops in Taiwan, and mainly grown in the central to southern parts and the plain area in the eastern part of the island. Although the climate in Taiwan is advantageous to growing of sugarcane, it is also conducive to the prevalence of diseases and insect pests. Thus, protection of sugarcane from the invasion of diseases and insect pests plays an important role in sugarcane cultivation and also in securing increase in cane and sugar yields per unit area.

A total of 397 papers on sugarcane diseases and insect pests have been published

in the Report of Taiwan Sugar Research Institute and other journals during the period of 1945 to June 1983. Accomplishments made in the research of sugarcane diseases, management of sugarcane insect pests and development of biological control have been reviewed by Chu,¹⁶ Pan^{65, 66} and Cheng,¹² respectively. The objective of this review is to summarize the significant research achievements being obtained in past 30 years.

Major Diseases

Sugarcane disease problems in Taiwan are more complex, and a total of 54 diseases have been recorded. Since the prevalence of certain disease often results in elimination of a variety with good agronomic characters, more emphasis has been made on the research of host-pathogene relationships. The achievements on the research of 9 major diseases, development of control methods, and some minor diseases tending to increase their importance are described as follows.

Sugarcane White Leaf Disease (SCWL)

A new sugarcane disease very resemble to leaf scald (*Xanthomonas albilineans* (Ashby) Dows.) was first found on NCo310 in southern part of Taiwan in 1958.⁵³ The disease spread rapidly to Chisan, Yuching and Chiayi areas, and in 1966 to 1967, the incidence of SCWL was observed in all sugarcane areas except Yuemei, Taichung, and Chihu, the central part of Taiwan.⁷ Since the symptoms development and infection patterns of the disease were entirely different from that of leaf scald, the disease was presumed to be caused by a virus^{50, 54} and named as sugarcane white leaf disease in 1962.⁵⁰

Discovery of the insect vector, *Matsumuratettix hiroglyphicus* (Matsu.) by Matsumoto et al.⁵⁹ contributed greatly to the ad-

vancement of research on SCWL. Transmission characteristics of SCWL by the insect vector were clarified,⁵⁹ and the causal agent was proved to be a mycoplasma-like organism in 1968.^{46, 75} *Saccharum spontaneum* L. was also determined to be the host plant of the causal agent.⁴⁷ The research achievements on the causal agent, host plants, disease transmission by the vector, and control measures have been reviewed by Lee⁴⁰ and Chen.⁷

Efforts were made by several workers to control SCWL with thermotherapy and chemotherapy methods. Hot water treatment of the diseased seed pieces at 54° C for 40 min was effective in curing the disease, but the treatment seriously damaged the buds and resulted in poor germination.⁵¹ Treatment of diseased seed-pieces with tetracycline antibiotics only resulted in delayed appearance of symptoms for several months.^{48, 75}

It was found that the population of *M. hiroglyphicus* reached the peak during July to October, then declined rapidly in December to April.^{69, 92} High incidence of SCWL was generally found in July to September, and percent infection of SCWL on cane plants decreased significantly during January to March.^{8, 39} Thus, spring planting of sugarcane in February was recommended in the disease prevailing areas to prevent secondary infection of SCWL. This method combined with the use of healthy seed pieces, roguing of infected plants, and prohibition of growing ratoon in the infected fields has been successfully used for control of SCWL.

Sugarcane Mosaic

Four strains of sugarcane mosaic virus (SCMV), i.e., yellow stripe, short stripe, fine stripe and necrosis types have been found in Taiwan.⁵² Liu and Li⁵⁵ studied the reaction of sugarcane and the related plants to SCMV and found that *S. spontaneum*, *Miscanthus japonica*, and *Erianthus* sp. were immune to

the first three strains of SCMV. Chen⁶ reported that the purified SCMV is long flexuous rod with low level of aggregation, measuring $750 \times 13 \mu\text{m}$. The SCMV strains in Taiwan were classified on the basis of symptoms on differential host varieties as follows: the yellow stripe type = SCMV-A; the short stripe type = SCMV-B; the fine stripe type and necrotic type = mixture of SCMV-A and B; and an isolate from Badila cane = SCMV-D.²⁰

Recent studies on transmission of SCMV-A by aphid vectors revealed that *Rhopalosiphum padi* was the most efficient vector in transmission of the virus from sugarcane to sugarcane, while *Aphis nerii* and *R. maidis* were more effective in transmitting the A strain from corn to corn.⁹¹

Ratoon Stunting Disease (RSD)

Lo⁵⁷ examined sugarcane samples taken from 69 farms of Taiwan Sugar Corporation (TSC) in 1954 and found that 51% infection of RSD had occurred on NCo310, the leading variety in Taiwan during that time. RSD caused 17% loss in sugar yield in plant cane of NCo310, 20% loss in the first ratoon and 22% loss in the second ratoon.⁴² Owing to the severe infection of RSD on NCo310, treatment of seed pieces with 50° C hot water for 2 hr (HWT) was immediately applied for RSD control in 1954 and "HWT Nursery" was established for providing TSC farms with disease-free seed pieces. Contract nurseries were also established in 1956 for the farmers. Annual surveys conducted in 1954 to 1967 revealed that percent infection of RSD gradually decreased to 13.6% in 1966¹¹⁻⁶⁷. Hot air treatment of seed pieces at 54° C for 8 hr was recommended in 1973 due to intolerance of some varieties to HWT.¹⁸

Chen et al⁹ reported that a small coryneform bacterium measuring $0.2 - 0.3 \mu\text{m} \times 1.2 - 4.5 \mu\text{m}$ was consistently found in the fibrovascular extract of the diseased plants of NCo310 and 64-836. A large number of tiny

colonies developed on SC medium 2 weeks after incubation, and 64-836 seedlings showed RSD symptoms 3 months after inoculation of the isolated bacteria.¹⁰ Aerated steam therapy of diseased seed pieces at 55° C for 3 hr. resulted in almost complete curement of RSD.⁴¹

Downy Mildew

In Taiwan, sugarcane downy mildew (*Peronosclerospora sacchari* Shirai & Hara (*Sclerospora sacchari* Miy.) was introduced from Australia with sugarcane varieties in 1909. Growing of a susceptible variety POJ2878 during 1931-36 had resulted in the spread of downy mildew to the central and southern parts of Taiwan. Roguing of diseased plants was practiced for control of the disease, and no epidemic of downy mildew was found during this period.¹⁵

However, release of a moderately susceptible variety F134 in 1951 and trial growing of PT43-52 in 1952 again brought about severe infection of downy mildew in many localities. Downy mildew nursery was established at Shintsu in 1955 for the purpose of testing reaction of new clones to the disease by natural infection method.¹⁹ F108 (highly susceptible), NCo310 (resistant), F134 (moderate), H44-3098 (susceptible), and PT43-52 (highly susceptible) were used as the standard varieties. Owing to the unfavorable weather conditions in Shintsu, the downy mildew nursery was moved to Puli in 1964 and again to Nantou in 1968.

Interplanting of corn hybrid "Tainan No. 5" with sugarcane became a common practice in the contract farms in Chianan district in 1965, and this again caused an epidemic of downy mildew in the district. About 5,200 ha of sugarcane fields were infected by the disease in the crop year of 1965-66.¹⁹ Control campaign was immediately organized by TSC and the Department of Agriculture and Forestry, Taiwan Provincial Government, to suppress the spread of

the disease. In addition to roguing of diseased plants, interplanting of corn with sugarcane, or growing of corn in the infected fields were also prohibited. With these emergent control measures and the use of resistant sugarcane and corn varieties, the incidence of downy mildew declined rapidly and only 49.3 ha of sugarcane fields were infected in 1978–79.

The studies on artificial inoculation methods,³⁸ production of conidia and oospores in relation to environmental factors and mechanisms of infection^{60, 61, 96} and the relationships between the downy mildew of sugarcane and corn⁴³ contributed greatly to the development of control measures and varietal resistance tests.

Red Rot

Sugarcane red rot (*Physalospora tucumanensis* Speg.) had caused severe damage on rose-bamboo variety during 1905 to 1922.¹⁶ Lo⁵⁶ found two types of conidia in the imperfect state of the causal organism, but no attempt was made to determine whether these were the physiological races. Most of the new varieties released after 1952 possessed a high level of resistance to red rot. The incidence of the disease is now very scarcely found in the field.

Leaf Blight

Sugarcane leaf blight (*Leptosphaeria taiwanensis* Yen & Chi) only occurs in Taiwan, and severe infection of the disease has been found on F146, F156, F160 and F176 in some localities. An isolate capable of producing large amount of ascospores was obtained in 1970, enabling evaluation of varietal resistance by artificial inoculation method.^{33, 44} Three varieties, F167, F170 and F173 were found to have hypersensitive reaction to the disease.

Cercospora taiwanensis Matsumoto & Yamamoto was presumed to be the causal organism of sugarcane leaf blight.⁶² In 1952, Yen and Chi⁹⁷ observed *Leptosphaeria* fruit bodies on blighted sugarcane leaves, and the fungus was isolated and named *L. taiwanensis* Yen & Chi. They also considered *L. taiwanensis* to be the perfect state of *C. taiwanensis*. Further studies made by Hsieh²⁶ indicated that *C. taiwanensis* was very rarely isolated from the blighted sugarcane leaves and did not possess pathogenicity. On potato-dextrose agar or sugarcane-leaf-decotion agar *L. taiwanensis* produced *Stagonospora* and *Phoma* types of conidia in the same pycnidium. Thus, Hsieh²⁶ proposed the name of *Stagonospora tainanensis* as the imperfect state of *L. taiwanensis*.

Smut

Resurgence of the culmicolus smut (*Ustilago scitaminea* Syd.) occurred on NCo310 in 1964 in some localities in Taiwan. The disease spread rapidly with the increase in the acreage of ratoon, and in 1971–72, infection of the disease was found in 1,207 ha of sugarcane fields. Planting of the susceptible variety NCo310 and growing of ratoons in the infected fields were banned, in order to prevent continuous spread of the disease. It was found that Race 1 of the smut occurs widely in the western part of Taiwan, while Race 2 only invades F134 in Taitong area. Hsieh and Lee²⁹ reported that a new race of *U. scitaminea* could be induced by artificial mating of the two races.

An isolated nursery has been established at Suchongshi in 1975 for determining the reaction of new clones to the smut disease. Promising clones possessing moderate to high levels of resistance to downy mildew are again evaluated for smut resistance by artificial inoculation method. The incidence of smut has been confined to a limited area with these efforts.

Rust

Sugarcane rust caused by *Puccinia kuehnii* (Krüg) Butl. has been sporadically found in Taiwan. In 1977, severe infection of *P. melanocephala* Syd. occurred on F176 and more than 400 ha of sugarcane fields were infected. The symptoms caused by the latter species are minute and yellow spots in the early stage, then turn to dark-brown lesions and the disease prevails mainly in December to May. *P. kuehnii* also produces minute and yellow spots first, but the lesions become yellow brown in the later stage and the symptoms can be found in the field all the year around.²⁸ Hsieh et al.³⁰ found that uredospores of *P. melanocephala* lost their viability rapidly after exposure at 26° C or above.

Resistance or susceptibility of sugarcane varieties to *P. kuehnii* was found to be correlated with the rate of uredospore production on the varieties. The number of initial uredospores per sorus, or uredospore production per cm² leaf area per day was significantly lower on resistant varieties than that on susceptible varieties.³²

Leaf Scorch

Leaf scorch was first found on Co290 in Huwei area in 1948 and the causal organism was identified as *Stagonospora sacchari* Lo & Lin.^{49, 58} Extensive studies on the morphology, physiology of the pathogene, and dissemination of the disease were accomplished in 1951 to 1958. It was found that discharge of conidia from pycnidia occurred more frequently during rains, resulting in more rapid spread of the disease.⁷⁷ Leaf scorch could cause 28.1% loss in cane yield as the result of significant decrease in the number of green leaves in the infected plants.⁵⁸

Control campaign by eradication of the causal organism carried out in 1954 was effective in reducing the source of inoculum.¹⁶

The use of resistant varieties has resulted in very scarce incidence of leaf scorch.

Brown Spot

An unknown sugarcane leaf disease was found on F173 and F178 in Hualien in the spring of 1977. The disease was very similar to the brown spot caused by *Cercospora longipes* Butl. and the pathogene was presumed to be a new race of *C. longipes*.³¹ Wang and Lee⁸⁶ tested the reaction of 161 Taiwan and foreign varieties to the disease by artificial inoculation of conidia suspension (2×10^5 /ml) on 3 to 6 months old plants in the greenhouse. Although high level of resistance was found in NCo310, most of the varieties tested were moderate or susceptible to the disease.

The brown spots tends to spread rapidly and has been found in the southern and western parts as well as the eastern part of Taiwan. More studies on the causal organism and the factors associated with the spread of the disease are needed.

Root and Basal Stem Rot

Growing of ratoon cane in TSC farms at Yuching has been greatly interrupted by the prevalence of root and basal stem rot in recent years. The root and basal stem tissue of matured cane are rotted, finally result in a wilt of cane plant, and the severity of the disease increases with a succession of ratoons.²⁷ The causal organism was considered to be very resemble to the imperfect state of *Xylaria hypoxylon* (L. & Fr.) Grev.²⁷

Studies are underway to determine the range of host plants, perfect state of the causal organism, and varietal resistance to the disease.

Soil Fungi Associated with Poor Ratoon

During 1962 to 1963, poor germination and growth of ratoon was observed in

several TSC farms located at different localities. Chu et al.¹⁷ reported that more soil fungi, especially *Pythium arrhenomanes*, *P. catenulatum*, *P. mamillatum*, and *Leucoporous* sp., were found in ratoon fields than in plant cane fields. Since inoculation of the three species of *Pythium* in the soil resulted in retarded growth of plant cane and lower rate of germination in ratoon, they suspected that these soil fungi might be associated with poor ratoon.

Watanabe et al.⁸⁸ reported that 10 genera of soil fungi, i.e., *Fusarium*, *Trichoderma*, *Rhizoctonia*, *Marasminius*, *Pythium*, *Monilia*, *Colletotrichum*, *Phialophora*, *Humicola*, and *Thielaviopsis*, were more frequently isolated from sugarcane fields, occupying more than 81% of 1,010 isolates obtained. *Rhizoctonia* spp. were frequently isolated from poor or unemerged cane than from healthy cane, while *Thielaviopsis paradoxa* was most pathogenic and the fungus was isolated only from the poor or unemerged ratoon. They also presumed that these soil fungi, singly or in combination with some insects, appeared to be related to the poor ratoon.

Control Measures

1. Quarantine:

In Taiwan, sugarcane quarantine was started in 1914 and a quarantine nursery was established at Sien-Tang-Pieng, Tananchuan, Taichung, for inspection of sugarcane varieties introduced from other countries. The quarantine nursery was moved to Shitsu, Taipei in 1920, then incorporated into the Bureau of Commodity Inspection and Quarantine in 1957.

At present time about 60 to 100 foreign varieties are introduced every year, and they are first inspected at the quarantine nursery for 2 years, then those free from new diseases and insect pests are transferred to this Institute for further propagation. Invasion of Fiji disease, streak disease and gumming

disease was prevented by this quarantine system.¹⁶

TSC also strictly controls the movements of seed pieces from one area to the other to prevent spread of systemic diseases. Collection of seed pieces from the epidemic area is also prohibited.

2. Eradication:

Roguing of diseased plants has been effectively applied for control of SCWL, mosaic, downy mildew, smut and other systemic diseases. Sugarcane nurseries should be periodically inspected and the diseased plants should be removed and destroyed during the inspection. Reinspection of the nurseries is made by the plant pathologists from Experiment Stations of this Institute before collection of seed pieces. Nurseries with the infection of systemic diseases exceeding 5%, or with the incidence of SCWL or downy mildew are not allowed for collection of seed pieces.

3. Protection:

Control of sugarcane diseases with fungicide application is rarely made in Taiwan, except disinfection of seed pieces for control of pineapple disease (*Ceratocystis paradoxa* (Dade) C. Moreau). Immersion of seed pieces in 0.1% Benlate solution for 1 min has been recommended for control of the disease.⁸⁰

4. Varietal resistance test:

The use of resistant varieties has been considered to be the most ideal and effective method for control of sugarcane diseases. Thus, promising new clones selected each year are evaluated for resistance to the major diseases including downy mildew, smut, mosaic, leaf scorch, leaf blight, red rot, rust, and SCWL. Downy mildew and smut tests are repeated twice, and the resistance to both diseases is the prerequisite to the release of a new variety for commercial growing.

Cooperative program on disease resistance tests has been developed between this Institute and Hawaiian Sugar Experiment Station, U. S. Sugarcane Field Laboratory, Sugarcane Research Center, Fiji, and Indonesian Sugar Research Institute. About 20 to 30 sugarcane varieties are shipped to Taiwan every year from each of the institutes for testing varietal resistance to the major disease in Taiwan. This program has been of great significance in promoting mutual exchange of information on the research of sugarcane diseases.

5. Therapy:

As mentioned before, seed pieces to be planted in the nurseries in TSC farms should be treated with 54°C hot air for 8 hr for control of RSD. An attempt has been made to gradually replace hot air treatment with aerated steam treatment.

Sugarcane Nematodes and Control

Ten species of parasitic nematodes have been found in sugarcane fields in Taiwan.¹⁶ Examination of 13,697 soil samples taken from sugarcane fields at different localities during 1968 to 1975³⁵ revealed that the root-knot nematodes (*Meloidogyne incognita* Chitwood, *M. javanica* Chitwood) were more abundant in sandy and sandy loam soil, while the spiral nematodes (*Rotylenchus buxophilus* Golden, *R. robustus* (de Man) Filipjev, and *Helicotylenchus* sp.) occurred more frequently in the latosol. However, the occurrence of stunt nematode (*Tylenchorhynchus nudus* Allen), root-lesion nematode (*Pratylenchus pratensis* (de Man) Filipjev), and the stubby-root nematode (*Trichodorus christees* Allen) was found in different types of soils. Of these nematodes found in sugarcane fields, the root-knot nematode causes most severe damage on sugarcane roots.

Preplanting application of DBCP at the rate of 4 gal/ha resulted in 20% increase in cane yield, and the nematicide was recommended for control of parasitic nematodes in 1967 to replace D-D and EDB.¹⁶ Since the banning of DBCP, effective control of sugarcane nematodes has been obtained with application of Terracur P (5 kg a.i./ha), Thimet (3 kg a.i./ha).^{34, 36} Hu and Tsai³⁷ screened 62 sugarcane varieties for resistance to *M. incognita*. Most of the varieties tested were susceptible to the nematode, but less than 30% infection of the nematode was found in 4 varieties, H68-2235, H72-1522, H72-6095 and Q63. The reaction of interplanting crops to the nematode was also determined.³⁷

Major Insect Pests

Although 28 species of insect pests are commonly found in sugarcane fields in Taiwan, 11 species are considered to be of economic importance. The present status of these major insect pests and control measures are described as follows.

Matsumuratettix hiroglyphicus

Despite its early record in 1914,⁶³ *M. hiroglyphicus* remained unnoticed until the discovery of this leafhopper as the vector of SCWL in 1968.⁵⁹ The leafhopper is widely distributed in the central and southern parts of Taiwan and their host plants are restricted to sugarcane and *S. spontaneum*. In sugarcane fields, the leafhopper occurs abundantly in July to October, then the population declines rapidly in December to April.^{69, 92} Peak occurrence of the leafhopper on *S. spontaneum* is found in October to November and February to March.⁹² Six generations occur in a year with overlapping between the generations.⁶⁹ Oviposition habits of *M. hiroglyphicus* was found to be different from other species of leafhoppers.

The females lay eggs in the soil to a depth of about 0.5 cm and sometimes in the leaf-sheath near the ground.⁹² Parasitisms of *M. hiroglyphicus* nymphs by *Callidosoma matsumuratettix*,⁷⁹ *Pipunculus* sp., and a dryinid⁹⁴ were frequently found in September to December and appeared to be the important mortality factor of the leafhopper. Studies on the ecology of *M. hiroglyphicus* have been reviewed by Yang and Pan.⁹⁵

Studies on the characteristics of transmission of SCWL by *M. hiroglyphicus*⁵⁹ indicated that the leafhopper became infective 3 to 4 weeks after 1-week acquisition feeding. Transmissibility was very high and could be retained throughout the life once they became infective. No transovarial passage of the causal agent was found in the vector. The incubation period of the causal agent in sugarcane ranged from 3 to 6 months. Transmission of SCWL from sugarcane to *S. spontaneum* and *vice versa* by the leafhopper was also proved.⁴⁷ It was speculated that the leafhopper was primarily the feeder on *S. spontaneum*, then gradually attracted to sugarcane with the expansion of sugarcane growing in upland fields.

Sugarcane Woolly Aphid

The damage of sugarcane woolly aphid (*Ceratovacuna lanigera* Zehntner) on young cane plants generally occurs in March to May, resulting in poor growth or death of the plants. An outbreak of the aphid tends to occur when precipitations in September and October of the previous year are below averages and a temperature higher than 17.5° C prevails in January to February.⁷⁶ This relationship has been utilized for prediction of the occurrence of the woolly aphid.

Recent studies revealed that the degree of aphid infestations on different varieties varied significantly, and severe damages were found on F160 and F177. The development and fecundity of the aphid were extremely

affected by rearing of the aphid on ROC 1 and F172.⁷³

Sugarcane Moth Borers

Of the 5 species of sugarcane borers occurring in Taiwan, the grey borer (*Tetramoera* (*Argyroplote*) *schistaceana* Snell.) and the stalk borer (*Proceras venosatus* Walker) cause severe damages on the internodes of cane stalks. Annual loss of about 15,000 metric tons of sugar is due to the injuries of sugarcane borers, and more than 70.2% of the internode damages are caused by the grey borer.⁴⁵ The population of the grey borer generally increases in November to January and March to May. Peak occurrence of the stalk borer is found in April to May and September to October. Although the level of injury caused by the stalk borer is lower than that of grey borer, the stalks damaged are very easily broken by the wind.

The shoot borer (*Chilo traea infuscatella* (Snell.) Kapur) and the pink borer (*Sesamia inferens* Walker) mainly attack the young cane plants. The infestation of the top borer (*Scirpophaga nivella* F.) on sugarcane tends to decrease with the decline of the acreage of sugarcane variety NCo310 in recent years.

Soil Insects

Rapid increase in the acreage of ratoon in 1960s resulted in the outbreak of the sugarcane cicada (*Mogannia hebes* Walker) in several localities. Studies on the nature of nymphal injury indicated that vascular-bundle tissues of the roots are the main site of nymphal feeding, and that the salivary secretions could cause depressed germination in ratoon.^{64, 68} A negative correlation between the rate of germination in ratoon and the number of nymphs per stool was detected in the laboratory and field experiments.^{5, 74} In the crop year of 1965–1966, poor germination in ratoon was observed

in 668 ha of sugarcane fields.⁷⁴ Fallowing of the infested fields and deep plowing of the soil after the harvest of sugarcane were applied to suppress *M. hebes* population. No severe infestation of the sugarcane cicada has been found in recent years.

Sugarcane white grub (*Alissonotum impressicolle* Arrow) frequently occurs in clay loam and clay soils. The adults damage seed pieces planted in the field and basal part of the young plants in May to September. The most severe damage is caused by the 3rd instar larvae, resulting in poor growth or death of the cane plants. The larval density is highest in October to November, then gradually decreases in December to March.²⁴ Sporadic occurrence of *Anomala expansa* Bates and *A. cupripes* Hope are also found in sugarcane fields in recent years.

Sugarcane wireworm (*Melanotus tamsuyensis* Bates) occurs more frequently in acid soil, especially in the latosol, the red soil. *M. tamsuyensis* larvae are very sensitive to soil moisture; their activity increases at a soil moisture level of 15 to 20%.²³ The larval stage lasts for 2 to 3 years, and their damages result in poor germination of seed pieces, deadhearts in the young plants and significant decrease in cane yield. Injuries of wireworms and white grubs on sugarcane are also one of the limiting factors of growing ratoon in Taiwan.

Control Measures

1. Cultural control:

Cultural control plays an important role in management of sugarcane insect pests. Application of carbamate and organophosphorus insecticides in the soil before planting of sugarcane, or on the young plants resulted in effective control of *M. hiroglyphicus*. However, no significant decrease in percent infection of SCWL was observed in the treated fields.^{89, 90} As mentioned before, low incidence of SCWL on spring cane was

found to be attributable to the rapid decline of vector population in winter. Thus, planting of sugarcane in February was recommended to prevent secondary infection of the disease.

Deep plowing of the soil after the harvest of sugarcane and fallowing of the severely infested fields were effective in suppression of *M. hebes* population. These cultural practice and rotation with paddy rice are also used for control of white grubs and wireworms.

2. Host plant resistance:

Sugarcane varieties with dense parenchyma tissue in the mid-rib of leaves were found to be resistant to the top borer.¹ Rearing of *T. schistaceana* larvae with 4-month-old plants of F171 resulted in lower rate of larval survival and significant decrease in the number of eggs per female. Lowered degree of larval infestation on the internodes was also found in the variety.⁷⁰

Recent studies revealed that the seedling evaluation method⁶⁷ was also feasible for screening of sugarcane germplasm for resistance to *T. schistaceana*. The rate of seedling elimination by artificial infestation of the 1st instar larvae was generally lower in the crosses in which F171 was used as a parent variety.⁷¹ Less than 5.1% internodes were damaged by the grey borer in the progeny populations of F171 x F158 and F158 x F171, respectively. The resistant clones selected were found to have adverse effects on the larval development and fecundity of *T. schistaceana*.⁷¹

Nymphal survival and fecundity of the female adults of *M. hiroglyphicus* were affected by rearing of the leafhopper on F153 possessing high level of resistance to SCWL.^{92, 93} Further studies on the feeding mechanisms of the vector and its relation to transmission of SCWL will clarify the factors associated with sugarcane resistance to the disease.

3. Biological control:

Liberation of *Trichogramma australicum* Girault was found to be effective for control of the grey borer, stalk borer and the shoot borer.² However, a large scale release of the egg parasite was not made until 1972. Observations made in the crop years of 1972–1973 to 1974–1975 indicated that 37.3 to 54.4% decreases in borer infestations on the internodes of cane stalks were resulted from the release of the egg parasite at a rate of 100,500/ha during a period of 7–10 months every year.⁷⁸ Experiments conducted in 1974–1975 and 1975–1976 again proved the effectiveness of the use of *Trichogramma* for sugarcane borer control.¹⁴

T. australicum has been mass produced with the alternate host, *Corcyra cephalonica* Stainton, in each sugar mill of TSC and periodically released to sugarcane fields. A mass-production center was also established at Hsingying Experiment Station of this Institute in June 1979 for the purpose of supplying the egg parasite for release in TSC farms and farmers' sugarcane fields in Shingying district. Very recently, the egg parasite was identified and confirmed by USDA to be *T. chilonis* Ishii.¹³

During the past 27 years, 16 species of parasites were introduced from West Indies, India and U. S. A. in the attempt to control sugarcane borers.¹² Establishment of *Iso-tima javensis* Rohver, the larval parasite of top borer, in sugarcane fields was proved.^{2, 12} Although the progeny of *Lixophaga diatraea* Townsend, *Sturniopsis inferens* Townsend and *Trichospilus diatraea* Cherian & Margabandhu were collected from the fields after they were released,^{2, 3, 4} further investigations revealed no evidence of the establishment of these parasites in sugarcane fields.¹²

Experiments were made to control *M. hebes* with *Isaria sinclairii* (Berk) Lloyd and *Metarhizium anisopliae* (Metch) Sor. in 1970 to 1972.⁸⁷ Application of the fungi with

the media in ratoon fields at a rate of 100 cultural flasks/ha resulted in considerable increase in percent parasitism of *M. hebes* nymphs. However, studies are still needed to determine the optimum inoculation size and the effect of soil conditions on disease infection.

4. Chemical control:

Effective control of the sugarcane woolly aphid has been obtained with the spray of Malathion or Metasystox-i on young plants in the early stage of aphid infestation. Aerial application of ULV Ambithion or Sumithion at the rate of 1 l/ha, or Metasystox-R (6.25% solution) at the rate of 3 l/ha was found to be more effective and efficient for control of the aphid.⁷²

Application of aldrin or heptachlor in the soil before planting of sugarcane was very effective in protecting the plant cane and 2 successive ratoons from the injuries of white grubs and wireworms.¹¹ An economic threshold of 1 larva/stool was also established for these soil insects.¹¹ Development of resistance to heptachlor was found in wireworm populations 15 years after the first use of the insecticide.²²

Since the banning of the use of aldrin and heptachlor in 1975, Terracur P, Thimet and Counter have been used at the rate of 3 kg a.i./ha for soil insect control.^{21, 25} However, preplanting application of either of these insecticides often fails to control severe infestations of white grubs and wireworms in ratoon fields. Recently it was found that preplanting application of Terracur P or Counter followed by side-dressing 4 to 6 months after planting of sugarcane resulted in more effective control of the soil insects.²⁵

Wild Rats Control

Bandicota nemorivaga Hodgson, *Rattus losea* Swinhoe, and *Mus formosanus* Kuroda are the important wild rats damaging

sugarcane in Taiwan.^{81, 84} Overlapping of young and old sugarcane plants are very conducive to the abundance of wild rats, and their damages generally become more severe during the maturing stage of sugarcane. The severity of rat damage is also closely related to the degree of lodging of sugarcane plants.⁸³ Wang⁸⁴ reported that species composition of the rats varied significantly with growing stage of sugarcane and localities. During the young stage of sugarcane (February to June), about 80% of the rats captured were *R. losea* and *B. nemorivaga*. The number of *R. losea* increased gradually during the growing season of sugarcane (July to October), reaching 74–76% of the total populations of the wild rats. *M. formosanus* was more abundant in October to the harvest season.

Despite the extensive use of Warfarin during the past years, there was no evidence of development of warfarin resistance in the wild rats.⁸³ Field experiments conducted in 1968–71 indicated that 80 to 90% control of the wild rats was obtained with application of 1% zinc phosphide baits at the rate of 1 kg/ha.⁸² However, rejection of the baits by wild rats has been found in some localities. Application of 0.005% Klerat baits at the rate of 1–2 kg/ha during October to March was recommended in 1979 to replace zinc phosphide.⁸⁵ Studies are also in progress to develop pellet baits for aerial application of the rodenticide.

Conclusion

More emphasis has been made on the study¹⁾ of sugarcane varietal resistance to major diseases during the past years. Further studies on the mechanisms of resistance and the inheritance of disease resistance in sugarcane will greatly enhance breeding for resistant varieties. Economic importance of certain leaf diseases still remains unknown, and their prevalence in relation to varieties and environmental conditions should be

clarified. Pathological studies on the causes of poor ratoon found in recent years should be also emphasized.

Long growing period of sugarcane, stability in sugarcane ecosystem, and the less use of insecticides in sugarcane fields are apparently favorable to biological control of sugarcane insect pests. A large amount of sugarcane germplasm is already available and this will allow more fundamental studies on sugarcane resistance to the major insect pests. Development of integrated pest management for white grubs and wireworms is also urgently needed.

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Research and Development on Fuel Ethanol Production from Bagasse or Pith at Taiwan Sugar Research Institute

Sang, S. L., Wang, L. H., Hsie, M. C., Yee, W. F.

Abstract

Fuel ethanol produced from renewable resources is of great interest to those countries seeking to lessen their dependence on imported fossil oil. Cellulosic biomass of the renewable resources are considered to be of potentially significant raw material for fuel ethanol manufacture.

In Taiwan, both the fossil energy and biomass are in deficit; however, some cellulosic residues or wastes present here, such as rice hull, straw, bagasse and bagasse pith, still can be used as raw materials. Among these biomass the bagasse or pith represents one of the main feedstocks in Taiwan. Considerable research and development work on bioconversion of bagasse or pith are underway at Taiwan Sugar Research Institute. It includes the studies on production of xylose from bagasse or pith, ethanol fermentation from xylose, saccharification of ligno-cellulosic biomass, direct microbial conversion of cellulosic biomass by thermophilic anaerobic bacteria (*Clostridium thermocellum* and *C. thermosaccharolyticum*), and some alternative approaches with by-product production (α -cellulose and pulp). The results obtained to date show significant progress in some studies. A process of low liquor ratio and counter current washing system for production of high xylose content hydrolysate from bagasse pith has been developed. Remarkable progress in the ethanol fermentation from xylose has been also obtained by the process of isomerization

and fermentation in two separate reactors. An ethanol cost estimation has been made based on three different cases. The analysis shows that the results are encouraging. However, the efficiency of the fermentation and the ethanol concentration should be further improved in order to obtain an economically viable process in the future.

Some alternative researches have been also carried out for the α -cellulose or pulp manufacture from exlose-extracted bagasse. Although a qualified α -cellulose could be obtained, the pulp quality is still lower than the standard specification.

Introduction

Biomass traditionally plays an important role in providing human needs. It is estimated that the annual biomass production (90% in trees) from net photosynthesis in the world is about ten times higher than the world's total annual energy consumption^{2,4}. These renewable natural resources will continue indefinitely to supply us the fuel and have been considered to be one of the main potential substitutes for fossil fuels. However, the most energy consumed today is in liquid form of fossil oils, especially for the transportation; the ligno-cellulose biomass is thus not suitable directly for the modern use and should be converted into liquid fuel such as ethanol, methanol or synthetic fuels, etc.⁵. Research work on bioconversion of cellulosic biomass has been made at many institutes in the world for

many years since the energy crisis happened to us. But so far no commercialized process has been actually developed.

Taiwan has no enough natural resources. Both the biomass and fossil energy are in deficit. Hence, the liquid energy production from biomass is not likely to be encouraged here. However, Taiwan is located in subtropical and tropical area, and there are abundant cellulosic residues such as bagasse, bagasse pith, rice hull, and straw, etc.⁴ All of these can be utilized as raw materials for bioconversion. The surplus bagasse in each crop year is around 500,000–800,000 tons (wet base) in TSC sugar mills. Since it is industrially packed in bales and no collection cost is required, the utilization of bagasse or bagasse pith as raw material for liquid fuel production will be an economically viable option. This paper is a general report on the recent studies of bioconversion of bagasse or pith to fuel ethanol with emphasis on the technical feasibility and economical potential of different approaches under the situations in Taiwan.

Research Activities

Main Objectives

The main purposes of the research work, as mentioned above, are to develop the processes of bioconversion of lignocellulosic biomass, bagasse or pith, into liquid fuel, ethanol. It involves (1) to develop a process for production of higher xylose content hydrolysate from bagasse with less acid consumption; (2) to develop a technically and economically feasible process for ethanol fermentation from xylose; (3) to work out some possible approaches for saccharification of lignocellulose from bagasse; (4) to study the direct ethanol fermentation from cellulosic residue of bagasse or pith; and (5) to find out some alternative methods for production of ethanol from hemicellu-

lose and by-products, such as pulp and α -cellulose, etc.

Research Results

1. Xylose production from bagasse or pith by acid hydrolysis:

Lignocellulosic biomass is composed of three basic components, cellulose, hemicellulose, and lignin. Cellulose is a polysaccharide chain of anhydrous glucose units, mostly in crystalline form and is about 35 to 40% of the dry weight of the bagasse. Lignin is a complex amorphous polymer of phenylpropane units, and is a water insoluble chemical comprising about 20 to 25% of the dry weight. Hemicellulose is a polysaccharide made up of short chain amorphous polymers, and those from bagasse or pith are mostly anhydrous xylose units. It comprises about 30% of the dry weight of the bagasse and is easily hydrolyzed to monomer, but during the hydrolysis the xylose product is also easily degraded to furfural and other compounds. In general, the xylose concentration and the yield on total xylose content in bagasse obtained from conventional process are very low. It is around 2–5% and 60%, respectively. However, a mild acid hydrolysis process with low liquor ratio and counter current washing system has been developed at this Institute.^{8,9} Both the xylose concentration and the yield could be up to 17–20% (w/v) and 86%, respectively. The process developed was considered as a breakthrough in product concentration and yield; however, the new and the conventional processes were too much in acid consumption, requiring 0.2 tons of H_2SO_4 per ton of dry bagasse. Further work will be emphasized on reduction of acid consumption. It is expected that the acid consumption could be reduced to 0.01–0.02 ton per ton of dry bagasse (t.d.b.) or tenth of the original figure in the near future. The detailed operating conditions and results are shown in Table 1.

Table 1. Results of xylose production from various processes

Process	Conditions of hydrolysis							Xylose	
	Conc. of acid (%)	Liquor ratio	Acid used (T./T.d.b.)	Prehydrolysis		Post-hydrolysis		Yield (%)	Conc. (%)
				Temp. (°C)	Time (min)	Temp. (°C)	Time (min)		
Conventional	3.3	6.0	0.2	—	—	100	150	58	1.7
L.L.R.*	25	0.8	0.2	75	60	100	60	86	17
L.L.R. & D.A.**	1—2	1.0	0.01—0.02	120	75—90	100	60	70—80	17

* Low liquor ratio process.

** Modified L.L.R. process.

2. Ethanol fermentation from xylose:

Xylose or pentose are usually not fermentable to ethanol through conventional yeast fermentation. If it could be fermented, ethanol yield would increase considerably (30% hemicellulose in bagasse or pith). Theoretically, ethanol yield increases 75% as compared with the yield only from cellulose. Therefore, an incentive exists to develop viable fermentation processes, and it has been carried out at this Institute in three different ways as follows:

- (1) Isomerization of xylose to xylulose, and ethanol fermentation from xylulose by conventional yeast in one reactor.
- (2) Isomerization and fermentation with two separate reactors in a series flow system.
- (3) Direct ethanol fermentation from xylose by special microorganism, *Pachysolen tannophilus*.

The first approach with xylose isomerization and ethanol fermentation in one reactor has failed, because the optimal conditions of the two reactions were so different that they were unable to work effectively in the same one reactor. In order to proceed both reactions at the respectively favorable conditions, the second approach⁶ was designed in such a manner that the immobilized xylose-isomerase and immobilized

viable yeast cells packed in two separate tubular reactors were used for bioconversion from xylose to xylulose and from xylulose to ethanol. A xylose solution with a concentration of 16% (w/v) was passed through these two columns (isomerase packed column and yeast packed column) in series. Since the conversion constant from xylose to xylulose was very low, the reaction was impossible to be completed in one pass. Therefore, a recycling system was arranged. The effluent from the top of the yeast packed column containing a mixture of unreacted xylose and ethanol product was continuously recycled into these two reactors (columns) in series again for further

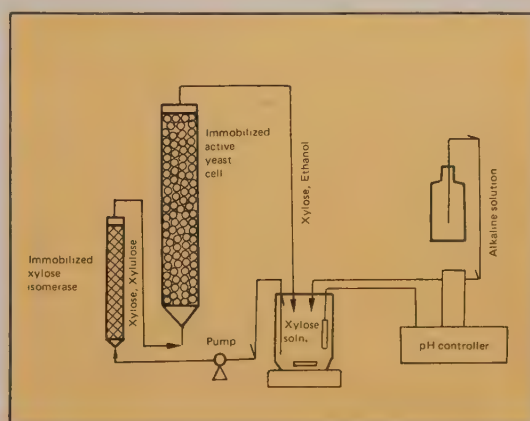


Fig. 1. Ethanol production from D-xylose by immobilized D-xylose isomerase and active yeast cell in two separate tubular reactors.

reaction until the whole conversion was finished. The detailed design and flow system are shown in Fig. 1.

The result showed that after 60 hrs recycle running with a flow rate of 480 ml/hr and a space velocity of 0.24, all the xylose originally presented in solution was exhausted, and the final ethanol concentration was around 4.68% (w/v) or 6% (v/v). The fermentation efficiency was about 61%.⁶ It is encouraging that commercially viable process for the ethanol fermentation from xylose could be developed in the future. Especially the situation like in Taiwan with higher gasoline price than in the world's market, the process holds more promise for development. The third approach was to convert xylose to ethanol directly by a special strain of *Pachysolen tannophilus*.

The ethanol concentration obtained was only about 2.09 to 3.01% (w/v), and the approach was less promising. However, the process was much simpler in operation than the others. Further work is needed to improve the strains for both of the second and third approaches. A comparison of ethanol fermentation from xylose between direct and indirect processes are shown in Table 2.

3. Saccharification of cellulose in bagasse or pith:

Conversion of cellulose to glucose or fermentable sugars by acid hydrolysis has a rather long history.^{5,7} There are two basic processes, the low temperature concentrated acid hydrolysis process (typically 41% HCl used) and the high temperature dilute acid hydrolysis process (0.5–2% H₂SO₄ at 180°C–200°C).

The latter process using dilute acid at high temperature usually gets less sugar yield (about 60%) than the former one, but the former process requires the additional equipment for acid recovery. Although they are being considered to be technically feasible, none of them have proved to be economically viable. Recently a number of studies on various saccharification of cellulose including rapid decompression for destruction of cellulose crystalline structure, acid and enzyme hydrolysis have been also carried out at this Institute. A modified low temperature and high concentrated acid process³

Table 2. Comparison of ethanol fermentation from xylose between direct and indirect fermentation processes

Process	Ethanol conc.		Fermentation eff. (%)
	(%, w/v)	(%, v/v)	
Direct fermentation	2.09	2.6	61
" "	2.69	3.4	52
" "	2.90	3.7	45
" "	3.01	3.8	37
Indirect fermentation (Isomerization)	4.68	5.9	61

Table 3. Hydrolysis of cellulose in pentose-exhausted cellulosic residue

Run number	Raw material		HCl acid		Liquid/solid ratio	Hydrolysis time (hr)	Glucose		Ligning (wt) (g)	HCl		
	Wt (g)	Pot. G (g)	Conc. (%)	Wt (g)			Prod. (g)	Recy (%)		Recy (%)	Left (%)	Lost (%)
11–15	32.9	21.62	42	115.2	3.5	15	19.43	89.87	13.5	90.3	5.3	4.4
16–20	22.8	14.98	42	91.3	4.0	3	11.24	75.03	11.7	91.0	5.2	3.8
21–25	25.0	16.43	42	100.0	4.0	4	15.10	91.91	10.0	91.0	5.0	4.0

Conc. = concentration, Recy = recovery, Pot. G = potential glucose, Prod. = produced.

has been developed. The process will avoid the difficulties of pumping concentrated hydrochloric acid through the residue and separating lignin from oligosaccharide solution in the conventional process just by blending the residue with acid in a simple machine and postponing the separation of lignin until the end of saccharification. The main results are listed in Table 3. The results show that both the glucose and acid recoveries could be up to 91% when it was operated under the optimal conditions with a liquid/solid ratio of 4, and hydrolysis time of 4 hours.³

Culture of a thermophilic microorganism — *Thermomonospora* sp., on bagasse was also attempted. The optimal medium composition and culture conditions for enzyme production were worked out. Although the enzyme was fairly thermal stable, the hydrolysis of cellulose was poor, possibly due to the crystalline form of the cellulose structure. A rapid explosive decompression trial was thus designed for destruction of cellulose crystalline structure. The operating pressure and temperature were 20 kg/cm² and 200°C, respectively, and the degree of crystalline was measured. The results (Table 4) show the process ineffective. The device for decompression and the operating condition should be further improved.

Table 4. Explosive decompression process for destruction of cellulose crystalline structure

Test no.	Conditions		Glucose yield (%)	Degree of crystallization (%)
	Acid conc. (%)	Time (min)		
2	0.5	8	Trace	38.2
3	2.5	24	4.5	33.4
4	5.0	10	9.5	29.1
5	10.0	10	2.7	25.6
Control				43.0

Pressure: 20 kg/cm², Temperature: 200°C

4. Direct microbial conversion of bagasse into ethanol:

Current efforts on direct bagasse conversion into ethanol by thermophilic anaerobic bacteria, *Clostridium thermocellum* and *Clostridium thermosaccharolyticum*, are aimed at increasing ethanol yield, improving tolerance to the ethanol product and reducing the production of by-products through screening and mutation of the above anaerobic bacteria. The preliminary research results obtained at this Institute are shown in Tables 5 and 6.

Table 5. Bagasse pith hydrolysis and alcohol production by *C. thermocellum*

Sample no.	EtOH (g/L)	Residue (dry wt, g)
12	0.12 (min)	0.747
14	1.12 (max.)	0.694
Average of 16 samples	0.49 (ave.)	0.660

Experimental conditions

Sample pretreatment: 2% NaOH pretreated.

Sample wt: 1 g of pretreated dry bagasse pith in 40 ml water.

Temp. 60°C, pH 7.2, Incubation time: 3 days.

Table 6. Bagasse pith hydrolysis and alcohol production by *C. thermocellum* & *thermosaccharolyticum*

Sample no.	EtOH (g/L)
14	1.60 (min)
4	2.96 (max.)
Average of 16 samples	2.26 (ave.)

Experimental condition

Sample pretreatment: 2% NaOH pretreated.

Sample wt: 1 g of dry pretreated pith in 40 ml water.

Temp. 60°C, pH 7.2, Incubation time: 3 days.

Table 7. α -Cellulose made from xylose-extracted bagasse

	Brightness (%)	Ash (%)	D.P.	Pentosan (%)	Purity (%)
Test sample	93	0.23	850	1.91	96
Standard specification	90	0.10	800	<5	95

5. By-product from xylose-extracted bagasse:

An alternative approach is proposed for production of α -cellulose or paper pulp from xylose-extracted bagasse, because the xylose extracted from bagasse still can be used for ethanol fermentation. It is expected that the xylose-extracted bagasse is technically possible to make qualified pulp or α -cellulose, since a pulp factory with a capacity of producing 100,000 tons of pulp each year is owned by Taiwan Sugar Corporation. It consumed yearly about 400,000 to 500,000 tons of bagasse as raw material. Most of hemicellulose or xylose in the bagasse are lost during the pulp processing in the factory. Therefore, the approach is considered as an economically viable option if the qualified pulp or α -cellulose could be produced from the xylose-extracted bagasse. Research work has been carried out for about one year. The preliminary results (Tables 7 and 8) obtained to date appear to be encouraging.

Table 8. Pulp from xylose-extracted bagasse

	Tensile test (K _m)	Bursting test (g/cm ² /g/m ²)	Tearing test (g/g/m ²)
Test sample	3.17	17.1	34.0
Control (unbleached)	8-9	50.0	50.0

67% xylose-extracted.

The α -cellulose made from xylose-extracted bagasse is proved be superior in quality and will meet the standard specification, except that the ash content must be improved by using more clean bagasse. However, the pulp from xylose-extracted bagasse is somewhat lower in quality. Much work has to be done for further improvement.

Economics of Ethanol Production in Taiwan

Economic estimate of ethanol production from ligno-cellulosic biomass is difficult, since a great deal of uncertainty still exists. It varies considerably depending upon many factors. According to some cost estimates in the world, the production of ethanol fuel from cellulosic biomass is not economic at present as compared with world oil price. However, the situation here is so different that some cellulosic biomass, such as bagasse, requires no additional collection cost, and it also requires no feedstock cost if the bagasse pith is used. Moreover, if ethanol production from cellulose and hemicellulose in bagasse is technically feasible, it will be more economic, especially in Taiwan where the gasoline price is higher than in the world market.

A preliminary cost analysis of fuel ethanol production in Taiwan from cellulose and hemicellulose in bagasse with three different

cases has been worked out! The sugar recoveries (glucose and xylose) by acid hydrolysis from bagasse or bagasse pith for all of the three cases are assumed to be 73–75%. The ethanol fermentation efficiency for glucose is 80% and the xylose is not utilized

in case I. It is also assumed that the fermentation efficiencies for glucose and xylose are 80% and 60%, respectively in case II and 80% and 80%, respectively, in case III. The results from calculation show that the production cost of ethanol will be NT\$21.9 per

Table 9. Alcohol cost estimation

	Lower investment		Higher investment	
Bagasse pith used (T/Year)	2×10^5	4×10^5	2×10^5	4×10^5
EtOH production capacity (KL/Y)	18900	41300	18900	41300
Capital investment (million NT\$)	(L) 600	(L) 1000	(H) 1530	(H) 2550
Cost of EtOH (NT\$/L)	37.4	32.1	42.2	38.0

Case I. Only cellulose from bagasse is utilized, and the fermentation eff. is 80%.

Table 10. Alcohol cost estimation

	Lower investment		Higher investment	
Bagasse pith used (T/Y)	2×10^5	4×10^5	2×10^5	4×10^5
EtOH production capacity (KL/Y)	29100	60600	29100	60600
Investment (million NT\$)	(L) 600	(L) 1000	(H) 1530	(H) 2550
Cost of EtOH (NT\$/L)	24.2	21.9	27.3	26.0

Case II. Both cellulose & hemicellulose are utilized & the fermentation eff. of glucose and xylose is 80% & 60%, respectively.

Table 11. Alcohol cost estimation

	Lower investment		Higher investment	
Bagasse pith used (T/Y)	2×10^5	4×10^5	2×10^5	4×10^5
EtOH production capacity (KL/Y)	32600	68100	32600	68100
Investment (million NT\$)	(L) 600	(L) 1000	(H) 15300	(H) 2550
Cost of EtOH (NT\$/L)	21.7	19.5	24.5	23.1

Case III. Both cellulose & hemicellulose are utilized & both the fermentation efficiency are 80%.

liter in case II with the capacity of 60,600 liters of ethanol produced per year, and NT\$ 19.5 per liter of ethanol in case III with the capacity of 68,100 liters of ethanol produced per year. The cost is quite close to or even below the present fuel price (NT\$ 26 per liter) in Taiwan. The fermentation efficiencies assumed in case II have been obtained in this Institute. The cost analysis shows that the research has the potential of developing an economical process in the future. The detailed cost analyses are shown in Tables 9, 10 and 11.

Conclusion

Taiwan is located in subtropical and tropical area. There are much cellulosic residues, including bagasse, bagasse pith, rice hull and straw, etc. All of these can be utilized as feedstock for bioconversion into liquid fuels. The surplus bagasse or pith is considered to be one of potential raw materials, because it requires no collection cost. Various approaches of bioconversion have been initiated in this Institute. It is found that a process with ethanol fermentation from xylose in bagasse by isomerization and fermentation using yeast in two separate reactors is one of the potential options. According to the cost analysis, if the ethanol production from xylose and cellulose in the bagasse has 80% fermentation efficiency, the process would be economically viable. The ethanol cost calculated with 60% fermentation efficiency from xylose as shown in case II has approached the local gasoline price and it appears to be worth while for further research.

An alternative approach for production of ethanol from xylose and α -cellulose from xylose-extracted bagasse has been developed. It is further expected to develop a process for production of qualified pulp from xylose-extracted bagasse in the near future.

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Research Projects in Progress

Sugarcane Breeding

1. Selection of prominent new clones.
2. Application of tissue and cell culture technique in sugarcane breeding.
3. Studies on interspecific and intergeneric hybridization in sugarcane.
4. Studies on the physiology of flowering of sugarcane.

Agronomy

1. Studies on the methods of herbicide application on cane field.
2. Drip irrigation for sugarcane.
3. Irrigation for sugarcane in gravel soil.
4. Surface furrow irrigation equipped with underground pipeline.
5. Subsurface drainage for improvement of saline-sodic soil.
6. Soil moisture management and sugarcane growth.
7. Water well degradation and its improvement.
8. Improvement of agricultural implements for sugarcane cultivation.
9. Studies on the base cutter automatic lifting system of cane harvester.
10. Studies on the topping mechanism of cane harvester.

Plant Nutrition

1. Use of ^{15}N to detect sugarcane response to nitrogen.
2. Improvement of the productivity of monocropping cane field.
3. Sugarcane response to nitrogen fertilization in high ground water table area.
4. Studies on the application of liquid mixed fertilizer on sugarcane field.
5. Effect of soil N-fixers on sugarcane growth.

6. Studies on mycorrhiza and nutrient uptake of sugarcane.
7. Requirements of manganese and copper micronutrients on sugarcane.
8. Determination of ammonium volatilization for nitrogen fertilization in cane field.
9. Nutrient uptake by sugarcane in sub-tropical rainy area.
10. Effect of deep irrigation on nutrient uptake of sugarcane.
11. Effect of long-term application of pesticides on soil property and ecology.

Plant Protection

1. Evaluation of new clones for resistance to major diseases.
2. Methods of screening sugarcane varieties for resistance to diseases.
3. Studies on major leaf diseases of sugarcane.
(1) Brown spot and leaf blight.
(2) Rust.
4. Studies on the basal stem rot of sugarcane.
5. Studies on sugarcane nematodes.
6. Studies on sugarcane mosaic virus.
7. Biological control of sugarcane insect pests.
8. Mechanisms of sugarcane resistance to moth borers.
9. Studies on sugarcane varietal resistance to *Ceratovacuna lanigera*.
10. Studies on the insect vectors of sugarcane mosaic virus.
11. Control of wild rats in sugarcane field.

Sugar Technology

1. Studies on floc formation of raw sugar.
2. Production of microcrystalline sugar.
3. Studies on the color development of

plantation white sugar in storage.

4. Studies on preparation of sucrose ester.
5. Studies on improvement of carbonation process in sugar manufacture.
6. Improvement of sugar color appearance in new sulfitation process.
7. Studies on preparation of flocculants.
8. Studies on the clarification of deteriorated cane juice.
9. Development of syrup flotation process.

By-product Utilization

1. Studies on treatments of waste stream from sugar mill.
2. Strain improvement for L-lysine pro-

duction.

3. Ethanol production from cellulosic residues.
4. Production of dissolving pulp from bagasse.
5. Utilization of microbial enzymes for production of 5'-nucleotides from ribonucleic acid.
6. Isolation of ligninase producing microorganisms and their application.
7. Studies on industrial enzymes production.
8. Studies on TSC mycin production.
9. Studies on utilization of refined soy protein.
10. Experiments on production of bagasse pulp for printing paper.



Conference of research project evaluation of TSRI.

Technical Service

Data Processing and Publication Center

Under the increasing demand of upgrading the research works in all aspects of sugarcane agriculture and sugar manufacturing, and establishing more effective research databases in this Institute, a sophisticated 32-bit supermini computer, DEC VAX 11/730, has been installed at this Center during the year.

Being versatile and of an entirely new generation, this computer is equipped with multi-usage functions to fit every case in time sharing and real time conditions. It is also capable for data acquisition and analysis, online experimental control, engineering simulation and design, and theoretical analysis in applications. It can handle interactive distribution, investment analysis and econometric modeling; and combining with word processing, electronic mail, graphics, data retrieval, statistics, and applications programming.

It is anticipated that with the complete implementation of this computer systems, our research level as well as all data processing performances will be greatly promoted.

Meanwhile, the functions of this Center including the editing of periodicals and publications of this Institute; the extensive bibliographic services of technical library; photographic services; xerox copying and offset printing services; and the annual evaluation on the result of research projects and the output of technical and managerial services of this Institute have also been successfully carried out within the year.

Extension and Training Center

During the year of 1982-83, the Extension and Training Center of TSRI successfully carried out several training programs

for TSC employees. In July - November 1982, 408 agricultural technicians from the sugar mills of TSC received a vocational training in different fields of sugarcane agronomy. Sixty participants selected from the sugar mills attended training in joint farming operation for sugarcane cultivation in December 1982. With the cooperation of Huwei, Hsingying and Pingtung Experiment Stations, the Center opened 31 classes in sugarcane cultivation with 1,240 attendants during January - June 1983. Training courses on sugarcane agronomy were given to 6 agronomists and sugar mill managers from Indonesia in March 1983.

The Center organized two annual seminars on sugarcane agriculture and sugar technology for the chiefs of agriculture and sugar industry divisions of TSC sugar mills. Research progress and new technical information were presented by the researchers of TSRI, and technical problems were discussed during the seminars.

In order to understand farmers' problems further, the Center also joined the Agriculture Inquiring Team and visited the rural area periodically. It was of significance in assisting farmers to solve problems in sugarcane cultivation.

Instrument Service Center

A micro-computer based controller, which was developed to arrange the sequence of several batch type centrifugals since last year, has been set up on site to investigate the control performance in Kao-hsiung sugar mill this year. The results were so satisfactory that the sixteen centrifugals either in one or two or three groups could be started individually with a permission signal from the controller; therefore, the total consumption of power was kept

within the rating value of the generator.

Besides the study of the application of micro-computer as mentioned above, this Center also endeavored to design and install different kinds of control systems, such as a central supervision system for defecation process in clarification in four mills, a central control system for sulfitation process in clarification in two mills, four monitoring systems in twenty mills, an automatic cane feeding system in one mill and another L-lysine purification control system in one by-product factory. All of these systems have been suitably accomplished in this year.

Chemical Analysis Center

This Center undertakes the chemical analysis of numerous samples from the TSC sugar mills and plantations. During

1982-83, about 10,000 samples in number were analyzed in due course. Among which, 500 samples of the products and by-products of sugar manufacturing including sugar, molasses and alcohol were examined for the quality control of manufacturing; 5,500 cane leaf samples from the plantations were analyzed for diagnosis of nutritional status of sugar cane; and 4,000 soil samples were analyzed for the intensive survey of field fertility.

Besides the aforesaid works, the Center also participated in the team work which aimed to survey current status of the 23 TSC sugar mills during the milling period, and the overall evaluation was made on the qualities of the harvested cane and manufacturing efficiency of the mills. The research project on the rapid assessment of cane biodeterioration was also carried out in the Center this year.



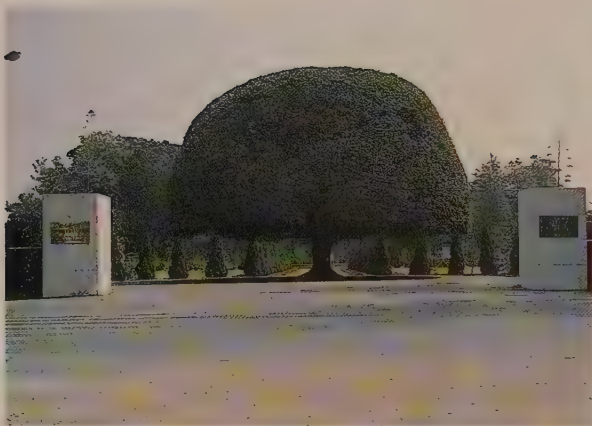
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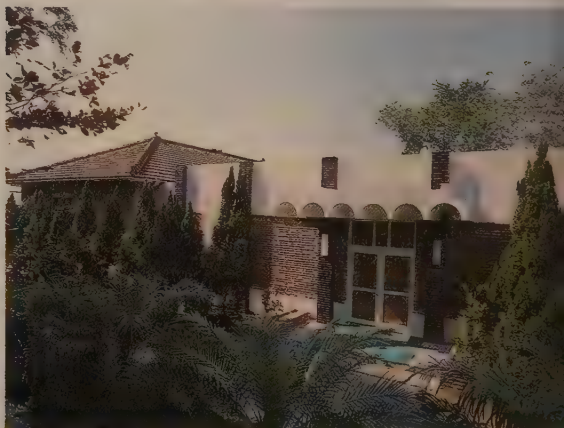
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- Use of computer on research development. (Dr. F. S. Cheng)
- The thought of contemporary science. (Dr. T. M. Lai)
- Research on applied microbiology. (Dr. M. Bae)
- The system and application of PRIME computer. (Mr. K. P. Tong)
- An introduction to VAX-11/730 computer. (Mr. J. C. Liao)
- The essentiality of application of computer. (Mr. S. Y. Tien)
- Strategy planning and research development. (Mr. F. C. Chen)
- Application of chromatography and electrophoresis in isolation of protein and amino acid colorants. (Dr. Helena)
- Nutrient starvation system. (Dr. R. L. Cook)
- Utilizing waste in agriculture. (Dr. Boyd G. Ellis)
- The principle of LASER and its applications. (Dr. H. P. Liu)
- Some notes on newly released sugarcane varieties ROC 7, ROC 8 and promising clones. (Mr. C. C. Lo)
- Principle of hydrostatic transmission system and its application in agricultural machineries. (Mr. L. H. Huang)
- Computerized data management of sugarcane soil fertility. (Mr. I. J. Fang)
- Recommendation of phosphor and potassium fertilizer in sugarcane field. (Mr. I. J. Fang)
- Biological control of soil-borne diseases in agriculture. (Dr. M. M. Kao)
- Recent progress in the research of sugarcane root-knot nematode. (Mr. C. H. Hu)
- Recent advance in biological control of agricultural pests. (Mr. W. Y. Cheng)
- Boiler efficiency and steam utilization. (Mr. C. S. Chen)
- Milling equipments and evaluation of milling efficiency. (Mr. W. L. Tsai)
- Key points of high speed machine settings. (Mr. G. C. Jing)
- Considerations in constructing a new sugar factory. (Mr. Y. J. Jau)
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- Piping in a sugar factory. (Mr. Y. H. Song)

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Scientists Sent Abroad for Advanced Studies, Investigation, or Participation of International Symposium

Name	Subject	Country	Date
M. C. Liu	5th International Association of Plant Tissue and Cell Culture	Japan	July 10 – 17, 1982
W. H. Chen	5th International Association of Plant Tissue and Cell Culture	Japan	July 10 – 17, 1982
W. Y. Cheng	Investigation on Biological Control of Insect Pests	USA	September 4 – October 3, 1982
C. C. Wang	Seminar on Nutrient Recycling in Agri- culture with Reference to the Utiliza- tion of Industrial Wastes	Japan	September 6 – 11, 1982
J. B. Chen	Advanced Studies in Plant Physiology	USA	January 1983 –
C. C. Wang	18th International Society of Sugar Cane Technologists Congress	Cuba	February 15 – March 8, 1983
C. C. Lo	18th International Society of Sugar Cane Technologists Congress	Cuba	February 15 – March 8, 1983
Y. S. Pan	Investigation on Biological Control of Soil Insects	USA	May 16 – 29, 1983

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